

SELECTIONS

FROM

THE RECORDS

OF

THE BENGAL GOVERNMENT,

P. W. D.,—IRRIGATION BRANCH.

Published by Authority.

N^o. I.

PAPERS FROM 1866 TO 1870,

REGARDING THE

DAMOODAH CANAL PROJECT.

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PREFACE.

Investigations connected with the River Damoodah having already been published in Selections from the Records of the Bengal Government, No. XL., the Lieutenant-Governor considers it will be useful for future reference as well as interesting to the general reader to complete the series by a compilation of the papers connected with the Damoodah Canal Project, so that when the scheme which the Supreme Government has ordered to be temporarily suspended is taken up again, all the necessary information concerning it will be found in the following pages.

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DAMOODAH CANAL PROJECT.



Part I.

DAMOODAH CANAL PROJECT.

FROM MESSRS. F. SCHILLER, A. T. T. PETERSON, AND F. A. GOODENOUGH,
to the Government of Bengal,—(29th June 1866.)

The inability of the East Indian Railway Company to meet the requirements of the public, and more especially of the rapidly increasing coal trade, has become so patent that we foresee considerable difficulties in the future for the coal interest which, by the opening of the East Indian Railway Chord Line, will rather be increased than diminished. In these circumstances our attention has been drawn to the feasibility of constructing a canal to connect the coal fields of Raneegeunge with the Hooghly. We believe that not only is such a scheme practicable, but that whilst the coal trade would be no longer jeopardized, it would otherwise greatly tend to insure the prosperity of the country through which it would have to pass.

Much of the land required for the canal in the neighbourhood of Raneegeunge actually belongs to colliery proprietors, who would gladly make it available for the proposed purpose, and lower down the chief owners are the Maharajah of Burdwan and Baboo Joy Kissen Mookerjee, who, we believe, would both cordially co-operate in the scheme. Small sections of land may, however, have to be taken up, as provided by law, and we presume Government would not object to allow this to be done under the provisions of Act VI. of 1857, which is the only concession which we solicit, together with the sole right of constructing the canal. The cost of the canal is roughly estimated at one crore of Rupees, and the time of construction at three years.

We would therefore ask Government to grant to us the sole right of constructing this canal, upon the condition of our raising the necessary capital for its construction within three years from the date of such concession, and we would also engage that, as soon as the capital is raised, the work be completed within six years from that time.

From the Government of Bengal, to the Government of India,—(23rd July 1866.)

I am directed to forward, for submission to the Government of India, a copy of a letter from Messrs. F. Schiller, A. T. T. Peterson, and F. A. Goodenough dated the 29th June last, containing a proposal for the construction of a canal to connect the coal fields of Rancegunge with the Hooghly.

2. The Lieutenant-Governor would recommend that, if the projectors submit a scheme for a canal for irrigation and navigation from the Damoodah River above Rancegunge to the Hooghly, which shall be approved by the Government, and agree to such a tariff of tolls and water-rates as the Government shall approve, the exclusive privilege they ask for should be conceded to them, and the land for the canal taken up under Act VI. of 1857 at the expense of the projectors.

From the Government of Bengal, to MESSRS. F. SCHILLER, A. T. T. PETERSON, AND F. A. GOODENOUGH,—(23rd July 1866.)

Your letter dated the 29th ultimo containing a proposal for the excavation of a canal to connect the coal fields at Rancegunge with the Hooghly River has this day been submitted to the Government of India in the Public Works Department, with the Lieutenant-Governor's recommendation that, if you submit a scheme for a canal for navigation and irrigation from the River Damoodah above Rancegunge to the River Hooghly, which shall be approved by the Government, and agree to such a tariff of tolls and water-rates as the Government shall approve, the exclusive privilege you ask for should be conceded to you and the land for the canal taken up under Act VI. of 1857 at your expense.

From the Government of India, to the Government of Bengal,—(Simla,
15th August 1866.)

I am directed to acknowledge receipt of your letter No. 2872 dated 23rd July 1866, regarding the proposed construction of a canal to connect the coal fields of Ranegunge with the River Hooghly.

2. In reply, I am directed to state that the Governor General in Council is disposed to consider favorably any project for a navigable canal with this view, and would be glad to see such a project encouraged under Act XXII. of 1863.

3. The question of combining irrigation with navigation in such a canal, as suggested by the Lieutenant-Governor, is one which must depend in great measure on the views of Her Majesty's Government on the reference which has been made to it as to the agency by which works of irrigation should be constructed.

4. His Excellency in Council believes that Captain Garnault, R. E., was employed for a considerable period in investigating the capabilities of the upper basin of the Damoodah for the formation of reservoirs, with the view of checking the floods and of feeding irrigation canals, but no final report on the subject has been received; and His Excellency in Council will be glad to know what progress has been made in drawing up a project for irrigation from this river.

5. The promoters of the present scheme should be informed of the state of the case as regards the prospect of irrigation works, which may ultimately, more or less, affect their project, and also that the East India Irrigation and Canal Company have offered previously to construct canals in this region, and may again put forward their claim under the provisions of Act XXII.

6. The East Indian Railway Company may also have to be satisfied that the project can be carried out without detriment to their trade or risk to their line and works.

7. These points will all doubtless be disposed of in due course if the promoters will proceed as required by the Act indicated.

From the Government of Bengal, to MESSRS. F. SCHILLER, A. T. T. PETERSON, AND F. A. GOODENOUGH,—(27th August 1866.)

In continuation of my letter No. 2871 of the 23rd July last, intimating that your proposal for the excavation of a canal to connect the coal fields at Raneegunge with the Hooghly River had been submitted to the Government of India in the Public Works Department, I am now desired to state that the Lieutenant-Governor is informed that His Excellency the Governor General in Council “is disposed to consider favorably any project for a navigable canal with this view, and would be glad to see such a project encouraged under “Act XXII. of 1863.”

2. The Government of India has further remarked that—

“The question of combining irrigation with navigation in such a canal, as suggested by the Lieutenant-Governor, is one which must depend in great measure on the views of Her Majesty’s Government on the reference which has been made to it as to the agency by which works of irrigation should be constructed.

“The promoters of the present scheme should be informed of the state of the case as regards the prospect of irrigation works, which may ultimately, more or less, affect their project, and also that the East India Irrigation and Canal Company have offered previously to construct canals in this region, and may again put forward their claim under the provisions of Act XXII.

“The East Indian Railway Company may also have to be satisfied that the project can be carried out without detriment to their trade or risk to their line and works.

“These points will all doubtless be disposed of in due course if the promoters will proceed as required by the Act indicated.”

MEMORANDUM

By LIEUTENANT-COLONEL W. D. SHORT, R. E., *Superintending Engineer, Presidency Circle, on the Report of LIEUTENANT H. W. GARNAULT, R. E., on the Exploration of the Upper Reaches of the River Damoodah.*

The expedition was undertaken to explore the upper reaches of the

Object of exploration of upper reaches of Damoodah to discover sites for reservoirs wherein to store excess flood which now in extraordinary seasons inundates a rich cultivable tract of 360 square miles, situated on right bank in lower reaches of river.

Damoodah and its tributaries with the view of discovering sites on the latter, suitable for reservoirs, wherein to store

the excess flood which the existing single channel of the river in its lower reaches cannot pass off, and which excess now finds vent by spilling freely over some 25 miles of the right bank, whereby, in a season of extraordinary flood, about 360 square miles of country are inundated. The permanent security, therefore, of this extensive area is the great object sought for.

Map of the basin of the Damoodah and Barrakur Rivers.

Drawings submitted to elucidate report.

2. The undermentioned Drawings, elucidating the report, are herewith annexed :—

Longitudinal Section of the Damoodah from Ramghur to its junction with the Hooghly River.

Cross Sections of the Damoodah at several localities above point where the Burrakur River falls into it.

Map shewing the sites of the reservoirs selected.

3. Owing to various causes Lieutenant Garnault was delayed at Burdwan until January 1864, thereby losing some months of the field season ; but had he traversed the country

Numerous data collected by Lieutenant Garnault, R. E., under difficulties, within a short period.

earlier, or before it had been drained, it would have doubtless proved unhealthy. However, during the two and a half months he was absent he actually took a longitudinal section of the Damoodah from the mouth of the great tributary, the Burrakur, to Ramghur, a distance of 100 miles, also thirteen cross sections, reconnoitred several of the tributaries and discovered suitable sites for four reservoirs.

4. Considering the great difficulties attending such operations in so wild a tract of country, I am of opinion that Lieutenant Garnault is deserving of much praise for the

Intelligence, energy, and perseverance evinced in exploration deserving of praise.

intelligence, energy, and perseverance evinced in meeting the orders of Government.

5. The springs of the Damoodah are situated at Toree, about 50 miles south-west of Hazareebaugh and 40 miles north-east of Ranchee, whence the course of the river is nearly

Position of head springs of Damoodah and general course of river to its mouth.

due east for a length of about 270 miles, when it suddenly turns due south, and in a further course of 68 miles falls into the Hooghly about 5 miles above the mouth of the River Roopnarain.

6. From the configuration of the country the tract within which sites for reservoirs can alone be met with is within the district of Hazareebaugh, that is, west of the Jumooncah tributary the boundary of the district, which is about 132 miles below the springs of the Damoodah. The country through which the river flows in that length is hilly, covered with dense jungle, very little populated; indeed but a few villages exist of the poorest description, consisting of two or three Sonthal huts, with no supply of water, and the bare necessities of life obtainable with difficulty from great distances, all which drawbacks have to be considered when treating of the formation of reservoirs even when suitable sites have been found.

7. The principal tributaries to west of Ramghur are the Chundroo or Gurhee and the Haharoo which fall into the river on the northern or left bank, and the Suphee on the southern or right bank; and below Ramghur are the Konaree and Jumooncah on the left bank. All the above are situated within the Hazareebaugh District. East of the Jumooncah the Khatree is the only tributary of importance on the left bank above the Burrakur, and on the right bank the Gurgee and Gowaie. These tributaries with numerous minor ones drain the country bordering the river along 177 miles of its course or to mouth of the Burrakur, which is the great tributary, the freshes in which being ever simultaneous with those of the Damoodah cause the high inundating floods in the lower reaches. Below the mouth of the Burrakur to the point where the Damoodah is first embanked on left bank, some 60 miles, the Nooniah, Singarun, and Tumlah are the only tributaries, and these drain a portion of the Poroolea and Burdwan Districts to the north of the Grand Trunk Road. Below the head of the protective works on the left bank there are no tributaries, the drainage of the country taking an easterly course and finding vent into the Hooghly. The only tributary on the left bank below the Burrakur is the Salce River, which takes its rise near the Susinea Hill, some 15 miles south of Rancegunge, and

Sites suitable for reservoirs limited to boundary of Hazareebaugh District owing to configuration of country.

The principal tributaries of the Damoodah.

passing Sonamookhee falls into the Damoodah about 15 miles above Burdwan.

8. The description given of the features of the channel of the Damoodah in the 13th to 23rd para-

General features of the channel of river throughout its course.

graphs of the report is most interesting, shewing that from the head springs to

Ramghur, some 77 miles, the river flows through a wild hilly country between steep rocky banks and over a rocky bed, and these characteristics continue for some 25 miles beyond to Jullah, where seams of coal are first extensively met with along the bank; and here the channel first

Some 100 miles from head springs and 25 below Ramghur, channel first admits of timber being floated, and seams of coal are met with along bank.

admits of the timber cut from the Ramghur forests being floated down some 20 miles to Torree, where, owing to the existence of rapids which extend for $\frac{3}{4}$ of a mile, the timber is necessarily

Rapids at Torree $\frac{3}{4}$ of mile in extent; impediment to passage of timber.

conveyed by land to Rungamuttee or mouth of the Jumoonah tributary a

few miles below, and thence again floated without impediment down the river. From the Jumoonah to Tasra (which is situated just below the mouth of the Gowaie—the last tributary above the Burrakur), about 46 miles, the banks continue to be high and rocky, the bed of rock and sand; but beyond, the rock in bed disappears, the banks are less bold along some 25 miles to mouth of the Burrakur; east of which the bed is broad and sandy and the banks low and alluvial.

9. According to the great Trigonometrical Survey calculations,

Datum assumed.

the mean sea level is 11.63 above sill of Howrah Dock, and this datum has

been assumed; indeed it is to this that all the levels taken, or about to be, in the several Divisions west of Calcutta, have been directed to be reduced.

10. From the head springs of river to Ramghur, some 77 miles,

The fall in bed of river from head springs to mouth of river.

the fall is assumed at 6 to 8 feet per mile, and probably it exceeds this.

Between Ramghur at 260th mile and Gunklee in 248th mile the fall in bed is 6.56 per mile.

					Per mile.
	Between the 218th & 244th mile the fall is				17.5
	„ 244th „ 237th „ „				10.8
	„ 237th „ 235th „ „				14.9
	„ 235th „ 231st „ „				6.0
	„ 231st „ 214th „ „				5.75
	„ 214th „ 211th „ „				32.49
A. Just above mouth of Burrakur.	„ 211th „ 160thA „ „				4.53
B. Opposite to Raneegunge.	„ 160th „ 144thB „ „				3.5
	„ 144th „ 106th „ „				2.9
C. Opposite Burdwan.	„ 106th „ 83rdC „ „				2.5
	„ 83rd „ 48th „ „				1.5
D. Amptah, the limit to which the tides formerly allowed of the transport of heavily laden coal bunts.	„ 48th „ 24thD „ „				0.5
	„ 24th „ Hooghly River				0.79

11. Thus it will be seen that for some 12 miles below Ramghur the

The fall in bed along the first 132 miles of the Damoodah too great to admit of timber being safely floated down. Tramway to connect river bank with Grand Trunk Road proposed.

nature of the channel admits of timber being floated down, but for 13 miles beyond the average fall is 14.2 per mile. Below this rapid, advantage

is taken along 21 miles of a fall of only 5.87 per mile to float down timber when the greatest rapid in the channel is met with, having a fall of 32.49 feet per mile along a course of 3 miles, which necessitates land transport, so that the portion of the channel situated within the Hazareebaugh District, some 132 miles from head of river, is at present unsuited even to float timber. Arrangements should therefore be made to connect the Damoodah east of the Jumoonah tributary with the Grand Trunk Road by a tramway to facilitate transport operations.

12. Good judgment was exercised in the selection of the loca-

Good judgment shewn in selection of points for taking cross sections.

lities whereat cross sections of the river were taken, especially of

Nos. 1, 4, and 8, and the facts to be deduced from the examination of these data will be most valuable.

Cross section at Ramghur, 77 miles from source, affords good data.

At Ramghur (No. 1) 77 miles from

its source the river in the great flood of September 1863 flowed during two and a half days between the rocky banks 600 feet broad and 18 feet deep, draining some 1,300 square miles. At section No. 3, taken

at 55 miles below the above, the flood line was only 500 feet broad and 15 feet deep, but here the freshes are confined between a narrow gorge thrown back above, and the discharge can only be approximately calculated. Section No. 4, taken $1\frac{1}{2}$ miles to east and just below the mouth of the large tributary—the Jumooneah, shews the discharge of the channel at a most favorable point, that is, where the river has a more uniform section and the bed a fall of

Cross section below mouth of Jumooneah tributary equally favorable wherefrom to deduce calculations of discharge.

only 4·5 per mile. Of all the cross sections, that at No. 8, just above the point where the Burrakur pours its floods into the Damoodah, is the most valuable record. The great flood of September 1863 stood 850 feet broad within the rocky banks, and 20 feet deep; the flood lasted three whole days, and the calculations shew that 73,713,551,040 cubic feet of water was discharged, equivalent to a fall of 7·5 inches over the area drained, viz., 4,200 square

The volume discharged by the Damoodah in an extraordinary season above the Burrakur correctly ascertained.

miles. The rain-fall that caused such a flood was carefully gauged at 13 inches, and, as shewn by Lieutenant Garnault in his 33rd paragraph, the deduction fairly arrived at is that $\frac{3}{4}$ ths of the fall found vent through the channel above the junction of the Burrakur.

13. The rain-fall has been for some years carefully gauged at Hazareebaugh, and on 25th September 1863 it was 13 inches, or 5 or 6 inches in excess of any on record, and the floods on 26th rose higher and lasted

The data collected of the excessive rain-fall in the catchment basin in September 1863; the height and duration of the flood; the extent of country inundated carefully recorded.

longer (in the lower reaches especially) than any previous flood, except the great one of 1823, when the rivers of Bengal appear to have inundated the country to a fearful extent. We have, moreover, a very faithful record of the extent of inundation of 1861 submitted by Mr. Assistant Engineer Neuville, (who was specially deputed to the duty,) and which report was submitted with my special letter No. 229 of 29th May 1862.

14. The flood marks of 1863 have been carefully ascertained and shewn in the sections, so that the calculations of discharge may be considered very accurate, but as regards

Flood discharge in September 1863 carefully calculated and recorded, and may be assumed as the greatest on record.

the flood level of 1823 being 10 feet in excess of that of 1863, owing to the storm-wave holding back the freshes, I consider that such could not have been the case, and that the excess reported is to be traced to native tradition, as in those days there was not the same amount of European intelligence available to collect accurate data.

15. The sites selected for reservoirs, with the facilities afforded to store the rain-fall therein by construction of dams at favorable spots, are fully detailed in the 37th and eight following paragraphs of the report. The sites for reservoirs are doubtless confined to the country on left bank, the greater portion of the drainage falling into channel from the north.

Sites selected for reservoirs detailed in report.

16. By a reference to the maps on scale of 1 mile to the inch the suitability of the sites selected on the Chundroo and Haharoo tributaries will be recognized, as also the facility for the construction of dams; whilst the country that would be submerged is covered only with a short scrubby jungle, and compensation would be required only for a few huts: the cost and difficulty in constructing the dams in such a wild tract of country and that for the maintenance of the works would be considerable. These two sites for reservoirs appear to be the only ones available along 110 miles of the river's course, that is, as far as section No. 2 west of the Konaree tributary, and their capacity would not tend to afford much relief.

Sites selected for reservoirs and for formation of dams very suitable, but cost of construction of dams and maintenance would be heavy.

First two reservoirs proposed would not afford much relief.

17. The third site for a reservoir is situated in the Bakaroo Channel which falls into the Konaree tributary. The Bakaroo drains some 225 square miles of country south of the Hazarcebaugh plateau, and facilities would be afforded to store water at the site selected.

Third reservoir proposed would be more capacious.

18. The last and the fourth site selected is on the Konaree, the largest tributary above the Burrakur. The thorough exploration of this chauncel was not effected owing to
two feet deep. Fourth site for reservoir not fully explored, but sufficiently to show that it would be most suitable.

Lieutenant Garnault's sudden recall to his head-quarters, but the information collected shews that either one large reservoir could be formed by damming the channel a few miles above its mouth, or several minor reservoirs with dams on the higher reaches.

19. The question is to what extent these four reservoirs would

The proportion of the Damoodah flood that might be stored in the four reservoirs calculated at $\frac{2}{7}$ ths.

diminish the discharge, and the calculations shew that as regards the Damoodah flood about $\frac{2}{7}$ ths of the

volume, which now passes through the channel just above the point where the Burrakur falls into it, could be stored.

20. If the freshes in the Damoodah only had to be dealt with, there

To lower level of combined flood of Damoodah and Burrakur at Edilpore, near Burdwan, the main object.

would be no doubt as to the advisability of forming these reservoirs; more especially as several other, though

smaller, sites could be found on a more thorough examination of the country, but the point is to what extent the formation of these would affect the level of the combined flood of the Damoodah and its tributary, the Burrakur, at Edilpore near Burdwan.

21. In the 47th paragraph of the Report, Lieutenant Garnault

The reservoirs proposed calculated to store flood sufficient to lower level of inundation at Edilpore about one foot, and the consequent advantages.

states that the flood level at Edilpore, near Burdwan, would be lowered more than a foot, and he shews clearly by

the statements annexed that, of the thirty inundating floods which have occurred during the last five years, fifteen would have passed innocuously by this decrease of one foot in level, and of course the remainder would have been alleviated probably sufficiently so to have allowed the villagers to stay in their huts instead of living for two or three days in trees as they were compelled to do during the flood of September 1863.

22. This testimony to the misery endured during seasons of excess

Known results of inundation on right bank warrant adoption of remedial measures.

flood by a population scattered over such an extensive area shews the absolute necessity to endeavor to alleviate

their sufferings which are intensified by the uncertainty as to the course the spill flood may take. The country bordering the right bank may

be said to be undulating,—the villages being situated on the high ridges,—the flood passing through the intermediate valleys. The fluctuation in the volume of spill escaping through these numerous hollows is remarkable,—in one season the waters flowing at one locality 500 feet broad and 6 feet or more deep, and as they fall filling the low level with sandy deposit, the next year's flood forsaking the passage and creating a similar escape above or below. These vagaries of an uncontrolled flood, threatening one village this, and another the following year, naturally serve to keep the population scattered over the inundated area in a state of panic.

23. As each case of danger to a village community is taken up on

Adoption of partial measures of relief to suit particular requirements inexpedient.

its special merits by the Government in a humane and liberal spirit, and orders are given to protect the locality

by embanking against direct spill, the natural consequence is that the flood is thrown the next season in excess on the villages above or below, and these in their turn claim equal consideration; and if similar action continues to be taken, the free spill ordered to be provided over a certain length of the right bank will be gradually and almost imperceptibly interfered with; moreover this system of detached embankments only forces the spill to pass with greater velocity through the intermediate escapes, thereby scouring the country and forming numerous escape channels, all which cut up the bank and country and tend to increase the panic in the interior.

24. It is true that the uncertainty to life and property is not

Inundation within Burdwan District small compared to that in the Hooghly.

great in the Burdwan District, as there are but 96 square miles inundated, but the spill soon passes into

the Hooghly District, wherein 264 square miles are flooded, the level is much lower, and the inundation intensified by the freshes being held up on all occasions of simultaneous high springs.

25. It has been recorded by the late Superintendent of Embank-

Difficulties connected with control of inundation on right bank not yet overcome, consequently the question yearly opened.

Results of allowing the escape of flood over right bank recorded.

ments that the battle of the Damoodah had been fought and won, but dealing with the question in all its bearings, and with greater opportunities afforded

to judge of results, and above all studying the interests of the Government and the country, I venture respectfully to differ, believing as I do that the battle is an annual one, and that embanking continuously on the left bank and forcing the excess flood over the right has produced the under-mentioned results :—

1stly,—The embankment on left bank is but very slightly tried, the flood rising thereon but a few feet.

2ndly,—The absence of scour in the lower reaches has so deteriorated the channel that the coal traffic has been closed, that is, whereas Amptah, situated about 40 miles above mouth of river, was the great coal depôt, it has been abandoned, as large boats could no longer navigate the river.

3rdly,—The decreased scour in the channel along the portion where free spill has been provided has caused deposit in bed, which is being gradually raised in level.

4thly,—Insecurity to villages owing to vagaries of an uncontrolled flood, which entails endless petitions and necessitates re-construction of detached embankments which interfere materially with the full escape considered necessary.

5thly,—The great and increasing danger to the country to south of the Buxee Embankment (situated between the Damoodah and Roopnarain Rivers) owing to the spill flood of the Damoodah standing during an extraordinary season of flood an average height of $11\frac{3}{4}$ feet on the section for a period of two and a half to three and a half days until escape is found *via* the Roopnarain River,—such a test being excessive.

6thly,—The erosion that has taken place in the Roopnarain River below head of Buxee Khall, and which may be expected to continue owing to the action of the excess volume now gorging the Roopnarain Channel, has demanded retired lines, and now a further considerable retirement is necessitated, all which remedial measures entail outlay and loss of property.

7thly,—That there is ever the probability of the floods opening out on right bank a channel similar to that at Kistopore or Sreekistopore (both closed at considerable expense) and escaping in volume southwards, when the consequences would be serious.

8thly,—That in proportion to the deterioration of the channel of the Damoodah to south within tidal influence will be the decrease of volume passing up, and therefore a consequent loss of the power exercised by each ebb in scouring out the Hooghly at a most important point; and as the efficiency of a tidal channel is doubtless maintained by the volume ebbing in the channel itself and in the several tributaries, the deposit of sand at mouth of Damoodah will yearly gradually increase to the detriment of the Hooghly.

9thly,—That the deterioration of the channel of the Damoodah below Raneeunge and the difficulties in its navigation are yearly increasing as experienced by the Coal Companies, and as the Rail cannot compensate for this, the prosperity of the Coal Companies is affected.

10thly,—That ten years since the mouth of the Roopnarain, or rather the narrow clay bound neck, was only some 2,500 feet broad between the embankments and 2,500 feet long, and the section has been slowly but imperceptibly enlarging, entailing retired lines. Any disproportionate enlargement of this neck would be a most serious matter, for being in direct continuation of the Diamond Harbour reach the tides would pass in excess up the Roopnarain to the detriment of the Hooghly Channel, and as the volume at ebb in the former would be in excess, that in the latter would be held back, thereby increasing the tendency to the formation of shoals from deposit.

26. I venture to point out the difficulties to be contended against, because I am convinced that the whole would be overcome could the excess flood be stored in reservoirs. Having been all along of opinion that the Burrakur freshes should be first controlled, I hoped that Lieutenant Garnault would have been deputed to examine the line of country through which this river flows; however, the exploration has been carried out by an officer deputed by the East India Irrigation and Canal Company. From enquiry I learnt that there were no sites suitable for reservoirs; latterly, however, I have had reason to conclude that the investigation was not satisfactory. I would therefore strongly recommend that some one specially adapted for such work be appointed to visit the country immediately after the flood season of

All difficulties connected with excess floods to be overcome if suitable sites for reservoirs are found to hold up the Burrakur floods.

Exploration of upper reaches of Burrakur urged.

1865-66, for if sites are available the operations can be supervised more readily than in the Damoodah and the works maintained at a less cost, as labor is more abundant in this line of country, and this is urged as the difficulties and expense that would attend the formation and maintenance of the reservoirs on the Damoodah would, from the nature of the localities, be very expensive, and if sites are found on the tributaries of the Burrakur the immediate results would be more beneficial.

From LIEUTENANT H. W. GARNAULT, R. E., to the Superintending Engineer, Presidency Circle,—(24th June 1864.)

In Officiating Secretary to Government of Bengal's No. 6111, dated the 30th October 1864, I was ordered to explore the heads of the Damoodah and Burrakur Rivers in the manner proposed in my memorandum No. 157 of 30th July 1863, with a view of finding sites suitable for reservoirs to hold the surplus water which inundates the country in the lower reaches of those rivers.

2. I was relieved of the current duties of the Damoodah Division on the 1st January by Lieutenant Cumming, and started for Rauecgunge on the 4th, but was obliged to return on the 7th to appear before the Public Works Accounts Commission; so that I was not fairly started with the work till the 9th January when the field work season was half over: this delay was caused by the difficulty I experienced in obtaining the elephants I had indented for, and the time that elapsed before any officer was appointed to relieve me.

3. Lieutenant Cumming was transferred to Darjeeling in February, and no officer having been appointed in his place, I returned to Burdwan by your orders and resumed charge of the Division on the 1st April.

4. I was out, therefore, about two and a half months, and during this time I took a longitudinal section of the bed of the Damoodah from its junction with the Burrakur to Ramghur (a distance of 100 miles) and thirteen cross sections; besides this I reconnoitred four very suitable

sites for large reservoirs and several smaller ones,—a full description of which I shall give hereafter.

5. The country through which my route lay is very difficult. From the Jumooneah Nuddee (the boundary of the Hazareebaugh District) to Ramghur it is one mass of dense jungle and rocks. The few villages that exist are of the poorest description, consisting of two or three Sonthal huts, so that I experienced great difficulty in finding ground for encamping anywhere near my work, and was often compelled to send to great distances to obtain the bare necessities of life for my camp.

6. Accompanying this report are the following plans and sections:—

1 Map of the basin of the Damoodah and Burrakur Rivers.

1 Longitudinal section of Damoodah from Ramghur to its junction with the Hooghly above the James and Mary.

8 Cross sections of the Damoodah.

2 Maps on the 1-inch scale of the sites of the large reservoirs.

7. Of the section, the portion from Ramghur to junction with the Burrakur was taken by myself; the portion between the junction with Burrakur and Raneegunge I have put in approximately from the Railway levels; and that between Raneegunge and junction with Hooghly is from an old record in my office, the levels of which were, I believe, taken during my predecessor's incumbency of the Division. I closed with the Railway levels at Burrakur and took their datum, namely, the sill of Howrah Dock, but I have since reduced all the heights to mean sea level, allowing the latter to be 11·63 feet higher than sill of Howrah Dock according to the Great Trigonometrical Survey calculations.

8. In making calculations of the discharge of the river, I have used Eytelwein's formula, *viz.*, $D = 9\sqrt{2} \text{ fd} \times s$ where D =discharge, ft^3/sec , s =fall per mile in feet, d =hydraulic mean depth, and s =area.

9. I have marked on my sections the flood of 26th September 1863. Mr. Powell, Executive Engineer, was kind enough to drive in pins at the limit of the flood at two or three places near Burrakur, and in the higher reaches of the river I have taken the marks on the banks: where no marks were visible, I have obtained the height from the villagers. I have assumed this flood to be a maximum; and the rain-fall which caused it, a maximum rain-fall in twenty-four hours in the catchment basin.

10. These assumptions will, I think, give very safe data for determining the size and number of the reservoirs required, as the rain-fall recorded at Hazareebaugh on 25th September, *viz.*, 13 inches, is 5 or 6 inches more than any fall hitherto recorded; and the flood of September 26th rose higher and lasted longer, in the lower reaches of the rivers especially, than any previous flood since the memorable one of 1823.

11. The flood of 1823 must have been extraordinarily high: the marks of it have been pointed out to me from Cowcolly Light House to Ramghur, and it appears to have been at least 10 feet higher than any that has since occurred. In this flood, however, the Damoodah and all the other rivers in Lower Bengal were held back by the very high sea-wave which came up the bay and caused such destruction to life and property along the coast south of the Russoolpore River.

12. Before describing the reservoirs, I propose giving a sketch of the Damoodah River from its source: this has been already done some years ago by an officer far more able to do it than I am, and my only excuse for the repetition is that I have been able to collect more and truer information than was placed at the disposal of that officer at the time his report was written.

13. The Damoodah, or Deonud as it is called in the higher reaches of the river, rises in Toree about 50 miles south-west of Hazareebaugh and 40 miles north-west of Ranchee; it flows in an easterly direction through a wild country between high rocky steep banks covered with jungle and over a sandy and rocky bed; the fall appears to be about 6 or 8 feet per mile as far as Ramghur.

14. From Ramghur to south of Gunkee the river still runs in an easterly direction and through similar country; the bed, however, is more sandy and the fall is 6·56 feet per mile.

15. From Gunkee the river takes a northerly course to Julla or Mirzapore, and the fall is considerably increased, being to Gugree 17' 5", to Gaga 10' 8", and to Mirzapore or Julla 14' 9" per mile. The bed has several small breaks and is a mass of huge boulders which shew unmistakeably the terrific velocity of the river when in flood. The banks are very high, rocky, and covered with dense jungle.

16. Between the junction of the Bhera Nuddee and Gugree there is a hole or "dhow" in the river for a length of $\frac{1}{4}$ mile which is said to be unfathomable; the dry weather stream here is about 20 feet broad and runs between perpendicular rocks about 18 feet high; these rocks are themselves covered in floods.

17. At the angle formed by the junction of the Bhera Nuddee with the Damoodah there is a stone temple (Rajarapar mut) built by one of the former Rajahs of Echak and ministered to by a family of Brahmins who live at Hishapoora; the plinth of this temple was above the flood of 1863, but I was informed that the flood of 1823 rose up to the top sill of the doorway; it also lifted some of the stones of the steps and basement (about 8 cubic feet each) and deposited them 20 or 30 yards distant.

18. From Julla to Turceo the river again runs east and with a fall of from 5 to 6 feet per mile; the bed is principally of sand, with rocks cropping out here and there: the banks are high and a large quantity of coal is visible in them. From Julla the timber cut from the Raughur Hills is floated in rafts to Turceo where it is landed and conveyed by cart to Rungamattee; here it is again embarked and can proceed without impediment to Calcutta by the river.

19. Between Turceo and Rungamattee there is in 3 miles a fall of 100 feet or about 32.49 feet per mile; the bed in this portion has several breaks, and is a mass of huge boulders lying about in most bewildering confusion. Opposite Rajabera there is another "dhow" or deep hole similar to the one at Gugree already described.

20. From Rungamattee or the Jumoonah Nuddee to its junction with the Gowaie the river takes an easterly course and has a uniform fall of about 4.5 feet per mile; the bed is sandy and rocky, and the

banks are high and almost entirely of rock. Just above Tasra, for some distance, they have the appearance of having been cut to a regular slope of 2 to 1. The high flood line is very distinctly marked about $\frac{1}{4}$ th up the bank.

21. From Tasra to Raneegunge the slope of the bed is from $3\frac{1}{2}$ to $4\frac{1}{2}$ feet per mile, the banks are lower, very little rock appears in the bed, and the width between banks increases considerably.

22. From Raneegunge to opposite Burdwan the slope is about $2\frac{1}{2}$ per mile; the bed is broad and sandy,—the banks are low and alluvial. From Burdwan to Champadanga the fall is $1\frac{1}{2}$ feet per mile, and from Champadanga to junction with Hooghly about $\frac{1}{2}$ foot. From Amptah the Damoodah becomes tidal.

23. From its rise to its junction with the Hooghly the Damoodah has altogether a course of 337 miles in length.

24. The principal tributaries of the Damoodah are the Chundroo or Gurhee, the Haharoo, the Suphee, the Konaree, the Jumooneah, the Gurgee, the Khatree, the Gowaie, the Burrakur, and the Singarun.

25. The whole area drained by the Damoodah is about 7,600 square miles, of which 6,900 is drained just below its junction with the Burrakur. From Seilnah, or about 96 miles from its junction with the Hooghly, the river is embanked and receives little or no drainage.

26. In order to obtain some knowledge of the proportion of rain-fall which is drained by the river and that which is lost by evaporation, absorption, &c., I propose making a comparison between the rain-fall of September 26th at Hazareebaugh and the water that passed through the river at certain sections; the result will not of course be perfectly accurate, as I am dependent on the statements of the villagers for the duration of the floods; and the measure of the rain-fall is not, I think, as accurate as it might be on account of the rough instruments used in determining it.

27. The discharge, too, is not perfectly accurate as it has been calculated from the dry weather section of the river; there is a great deal

of sand in the bed of the river now which could not possibly have existed when the river was in flood, so that the depth and consequently the discharge is less as here shewn than it must actually have been. There is, however, to a certain extent a set-off against this error, as it is more than probable that before the flood came down there was some water in the river, of which I have taken no account.

28. On reference to the discharges noted on the sections, some inconsistencies will be observed; for instance, the discharge at Burkee is less than that to west of Gurgee, although between the two sections the volume passing down the river is increased by the drainage of the Gurgee Nuddce; so also with the sections at Tasra and Ghurbar. At Ghurbar the river goes over the bank and fills some low jheels which may account for the decrease in the discharge at this section, but I am unable to account for it at Tasra and Burkee, except by supposing that the flood line as pointed out to me by the villagers was not correct.

29. The sections which are, I think, most to be relied upon are Nos. 1, 4, and 8, *viz.*, those at Ramghur, west of Gurgee Nuddce, and above junction with Burrakur. At the latter, the flood limit was marked by Mr. Powell himself, and the two former sections were taken at the crossings of the Hazarecobaugh and Ranhee and Govind-pore and Ranhee roads respectively, where the heights of flood were well known. I shall use these three sections, therefore, in comparing the proportion of rain-fall drained by the river.

30. At Ramghur the discharge per second was 102,239.73 and the flood is said to have lasted two and a half days; the whole amount of water therefore that passed through the river was 22,083,781,680, which is about $7\frac{1}{2}$ inches of rain over area drained, *viz.*, 1,000 square miles.

31. At the section west of Gurgee Nuddce the discharge was 194,218.47 per second; the flood lasted three days, and the water that passed through the river was 50,341,427,424 cubic feet, which is equivalent to 7.2 inches of rain over area drained through that section, *viz.*, 3,000 square miles.

32. At the section above junction with Burrakur the discharge was 284,388·7 cubic feet per second; the flood is said to have lasted three days; the water that passed through the river was 73,713,551,040 cubic feet, which is equivalent to 7·5 inches over area drained, *viz.*, 4,200 square miles.

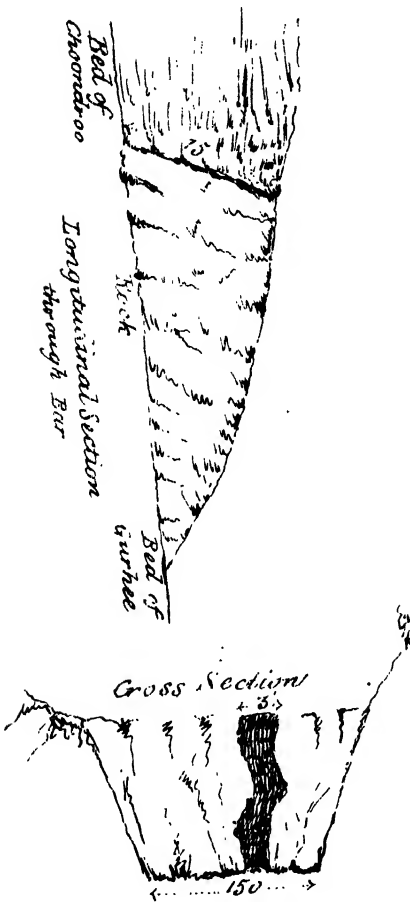
33. The rain-fall that caused the flood under consideration was 13 inches, and from the above calculations we find that 7·5 of this was drained by the river, the remainder being lost in evaporation, absorption, tanks, &c. $7\frac{4}{13}$, or $\frac{2}{3}$ rds say, is the proportion of rain falling on the catchment basin which passes through the river, and this is the proportion which the reservoirs must be capable of holding whether they are constructed to shut off a weekly, monthly, or yearly rain-fall.

34. As the first object of the reservoirs is to save the country below from inundations, which only occur three or four times a year after an unusually heavy shower of rain on the catchment basin, it will be sufficient to construct them capable of holding the greatest monthly fall: the floods run off so rapidly that ample opportunities would be afforded of emptying the reservoirs when the river is low, and so keeping them ready for receiving the next heavy shower; the last month's rain of the season might be retained in the reservoirs either for the purposes of irrigation or for feeding canals.

35. In Appendix B I have entered all the inundating floods that have occurred during the last five years as shewn by the Edilpore Gauge; when the flood rises up to 10 feet on this gauge it tops right bank. From the time that elapses between two consecutive floods, it will be at once seen with what facility the reservoirs might be emptied.

36. In Appendix A the rain-fall for each month during the last five years is recorded; the maximum in any month is 31·13: the reservoirs must be capable of holding $\frac{2}{3}$ rds of this, or 21 inches over the whole area the waters of which they receive.

37. The most suitable sites for reservoirs which I had time to examine are on the Gurhee, Haharoo, Konaree, and Bakaroo Nuddees. In speaking of these streams, I shall use the names given on the Revenue Survey Map, although they alter their names in each village through which they run.



38. The Gurhee is formed by two or three small streams which rise in the Kasiatoo and Joradug Hills; the last it receives is the Chundroo just above the town of Tendwa. In the mouth of the Chundroo there is an extraordinary natural bar of rock, through a fissure in which the stream runs. I have given in the margin a rough sketch of a longitudinal and transverse section of this bar. Opposite Tendwa the Gurhee is about 5 chains broad and has very high sloping banks. About 5 miles below Tendwa it runs between the Niree and Chiloomaree Hills, whose summits are less than a mile apart. The dam for the reservoir might be constructed in a

line between the villages of Utratoo and Chiloomaree.

39. The drainage of 185 square miles passes through the Gurhee, so that the reservoir would be required to contain (supposing as I have said before that it is to hold the available maximum monthly rain-fall) 7,736,256,000 cubic feet, and it would cover an area of 6 square miles and be on an average 48 feet deep: the valley through which the stream runs below Tendwa and before it enters the gorge between the hills is more than a mile broad and deep, so that there would be ample space for this water; the stream itself too would be

ponded up for 3 or 4 miles. The valley is principally grown over with short scrubby jungle, and the only villages that would, I think, be destroyed are those of Uhatee, Lorunga, Chiloomaree, and Sameedee which merely consist of a few Sonthal huts.

40. The Haharoo, which is the site of the next reservoir, is formed of the Sikree, Gulgullea, Bukwa, and Badmahee streams, all of which rise in the Hazareebaugh plateau: the Haharoo runs close under the Mondee Hill and then passes through a gorge about $\frac{1}{2}$ mile wide between the Acharoo and Angoo Hills,—the former being as it were a continuation of the Mondee Hill; this would be a suitable site for the dam. The Acharoo and Angoo Hills are almost perpendicular for $\frac{3}{4}$ ths of their height from the top, and then they slope gradually to the banks of the Haharoo, which are very steep and about 20 feet above the bed.

41. About 250 square miles of drainage passes by the Haharoo to the Damoodah, so that the reservoir would have to contain about 10,000,000,000 cubic feet of water and cover an area of 7 square miles with an average depth of about 53 feet: the valley above the dam and the beds of the streams themselves would, I think, give us this area, but apart from this it would be quite possible to relieve the large reservoir by forming small ones on each branch of the stream before they unite. I went up the Badmahee to its source and saw two or three such sites where a dam of 100 feet long only would be required. The smaller reservoirs would be more advantageous for irrigation, being situated higher up the valley, but it is just probable that the cost of three or four small dams and one moderately sized one would exceed the cost of the large dam in the Haharoo itself.

42. By the Gurhee and Haharoo reservoirs the discharge of the Damoodah at Ramghur would be reduced by about one-third.

43. The third reservoir would be formed by the Bakaroo, which rises south of the Hazareebaugh plateau, flows easterly through the Lugie and Jelinga Hills, and joins the Konaree about 4 miles west of junction of the latter with the Damoodah. A very suitable site for a

dam would be about 2 miles east of Lalgur, where the gorge between the Lugie and Jelinga Hills is not more than 1,000 feet broad. The Bakaroo drains 225 square miles : the reservoir would have to contain 9,400,000,000 cubic feet of water and would cover an area of 7 square miles to a depth of 48 feet. Before passing between the Lugie and Jelinga Hills south of Leyo the valley is very broad, and there would be no difficulty in storing this water : the villages on the banks of the stream where it enters the gorge, such as Lalgur, Dhundunya, &c., would be destroyed, but although they appear to be large villages from the map, they consist of two or three Sonthal huts only : the valley is of jungle which is very dense between the hills.

44. The fourth reservoir would be on the Konaree : the denseness of the jungle and my sudden recall to Burdwan prevented my making as complete an examination of the site for the dam as I could have wished and as I made at the other sites ; but a dam might be constructed between the Pureary Hill, which is a continuation of the Jelinga, and a ridge to the north of the Konaree, which runs along the left bank of Konaree and Damoodah. The Konaree carries the drainage of 550 square miles of country ; it would be necessary to store 20,000,000,000 cubic feet of water ; this might be retained in two or three reservoirs, one at the site above described, and others higher up the stream.

45. With these four reservoirs the discharge of Damoodah, just above its junction with the Burrakur, would be diminished by $\frac{2}{7}$ ths of the present discharge per second.

46. I have marked on both the large and small scale maps the site of the dams and the probable area and position that the water would occupy. I am unable to give approximately the cost of constructing the reservoir dams, but sites are so favorable, and good stone for building so easily obtained at each site, that I would recommend the necessary sections being taken, so that estimates might be framed for two of the dams at least, and from these some idea might be obtained of the probable cost of the whole project : the sites which would offer least obstacles for surveying and levelling would be the two western-most reservoirs, *viz.*, those on the Gurhee and Haharoo : the levels for these would probably occupy a good Surveyor about six weeks.

47. The reservoirs that I have already described would not of course be sufficient to save the country south of Burdwan wholly from inundation, but they would of themselves lower the flood level at Edilpore by more than a foot, and of the thirty inundating floods that have occurred in the last five years, fifteen would have passed innocuously down through the bed of the river : the danger caused by the remainder would have been greatly alleviated, probably sufficiently so to have allowed the villagers to stay in their huts, instead of living for two or three days in trees as they were compelled to do during the flood of September 1863.

48. The system of reservoirs is not unknown to the natives of the district, as on the road from Tendwa to Hazareebaugh, just below the Doongree Ghaut, I saw a dam, which a zemindar has constructed for irrigation across the Dinia Nuddee where it issues from the hills. The dam is strongly built of stone and brick about 100 feet long and 30 feet broad at top : there was, when I went over it on 19th March, a head of 6 feet of water on upper side.

49. In the Maunbhoom District, on the left bank especially, there are numerous small streams (locally called " jhoors") which rise a little south of the Grand Trunk Road and run due south to the Damoodah, carrying the drainage of about 10 or 12 square miles. These could all be very easily and cheaply dammed before they empty themselves into the river : the water thus retained, while causing a diminution in the discharge of the river, would be very beneficial to the country for dry weather crops : the ryots when spoken to on the subject readily admitted the advantage, but the universal question was who is to pay for the dam. Until the ryots, instead of being possessors, are simply cultivators of the land, such improvements by private individuals must not, I suppose, be expected. Of some of the larger of these streams which could be most easily dammed for reservoirs, I may mention the Gheejhoor, Kalajhoor, and Kaseajhoor.

50. After my survey during the ensuing cold weather, I feel sanguine of being able to point out more sites equally favorable both on the Damoodah and Burrakur, which will enable us entirely to control the floods in the river and at the same time afford means of irrigation to a country which is at present uncultivated for want of water. Now that

the tea producing capabilities of the Hazareebaugh District have been established, the land bordering on these mountain-locked lakes will become very valuable, and proceeds of the sale of the water for irrigation will go far towards covering the expense of the dams.

51. Before closing this report, I beg to offer a few recommendations with a view of obtaining further information regarding the Damoodah,—

1st,—That gauges be set up at Ramghur above the Burrakur Bridge, at Raneegunge and Edilpore, and that they be observed every three hours at least from 1st June to 30th October; there are gauges at Raneegunge and Edilpore; an establishment only is required to note the heights.

2nd,—That the rain-fall be recorded at the stations of Hazareebaugh, Ranchee, Burhee, Govindpore, Pooroolea, Burrakur, and Raneegunge; there are public offices at each of these places, and there would be no difficulty in keeping the record. A Register is kept at Hazareebaugh and Ranchee, but the gauge used consists of a tin funnel 2 inches in diameter, inserted in the neck of a bottle; the catching surface is hardly 4 square inches, and an ordinary bottle would not hold more than 8-inch rain-fall; whereas a 13-inch fall is possible, and it might all fall at night when it would be very inconvenient to measure off the rain and empty the bottle. The standard rain gauge which has a catching surface of 4 square feet should be adopted.

52. If it is decided that estimates should be framed for the dams at the sites I have recommended, I beg that two good Levellers may be entertained instead of the Sub-Overseer I had last year. It would be desirable also to have a Native Doctor attached to the establishment of the same grade as those attached to the Geological and Revenue Survey parties.

APPENDIX A.

STATEMENT shewing Rain-fall in each month from the Year 1859 to 1863 at different points in the Catchment Basin of the Damoodah River.

	1859.				1860.				1861.				1862.				1863.				REMARKS.
	Hazareebaugh.	Ranchee.	Bancoorah.	Burdwan.	Hazareebaugh.	Ranchee.	Bancoorah.	Burdwan.	Hazareebaugh.	Ranchee.	Bancoorah.	Burdwan.	Hazareebaugh.	Ranchee.	Bancoorah.	Burdwan.	Hazareebaugh.	Ranchee.	Bancoorah.	Burdwan.	
January	0.15	...	...	0.15	...
February	2.05	0.5	...	1.0	0.84	...	...	0.20	...	...	...	...	...	...	...	...	0.50	0.50	...	...	0.50
March	...	3.09	2.70	...	...	...	1.00	1.20	...	...	...	...	...	...	...	...	...	...	...	...	...
April	...	8.90	2.30	...	...	...	...	4.00	...	...	...	...	...	...	...	...	...	...	...	...	...
May	...	2.00	1.70	...	...	...	...	2.80	...	...	...	...	...	...	...	...	...	...	...	...	...
June	...	18.05	9.90	...	...	...	...	11.80	...	...	...	...	...	...	...	...	...	...	...	...	...
July	...	20.00	10.20	...	...	...	...	12.20	...	...	...	...	...	...	...	...	...	...	...	...	...
August	...	16.81	6.80	...	...	...	...	11.80	...	...	...	...	...	...	...	...	...	...	...	...	...
September	...	9.00	1.45	...	...	...	...	11.30	...	...	...	...	...	...	...	...	...	...	...	...	...
October	...	8.92	3.54	...	...	...	...	8.60	...	...	...	...	...	...	...	...	...	...	...	...	...
November	2.00	...	...	...	...	...	...	...	...	...	...	...	...	...
December	...	1.10	0.30	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

H. W. GARNAUT, *Lieut., R. E.,*
Executive Engineer, Damoodah Division.

APPENDIX B.
STATEMENT shewing all the inundating Floods that have occurred in the Damoodah River from the Year 1859 to 1863 inclusive.

Date.	1859.				1860.				1861.				1862.				1863.			
	June.	July.	August.	September.	October.	June.	July.	August.	September.	October.	June.	July.	August.	September.	October.	June.	July.	August.	September.	October.
1	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
2	5 6
3	10 6
4	8 9
5	7 6
6
7
8
9
10
11
12
13
14
15
16
17
18	5 1
19	9 9
20	8 10
21	12 0
22	9 3
23	7 0
24
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H. W. GARNAULT, Lieut., R. E.,
Executive Engineer, Damoodah Division.

From the Government of Bengal, to the Superintending Engineer,
Presidency Circle,—(28th September 1866.)

I am instructed to acknowledge the receipt of your memorandum, (without No. or date,) submitting, with your own remarks and observations, the Report No. A. dated the 24th June 1864 of Lieutenant H. W. Garnault, R. E., Executive Engineer of the Damoodah Division, on the exploration of the basin of the River Damoodah which, along with that of the head of the Burrakur River, was ordered to be carried out in the Orders No. 6111 dated the 30th October 1863, with a view of finding sites suitable for reservoirs to hold the surplus water which inundates the country in the lower reaches of the Damoodah.

2. In reply, I am to inform you that Lieutenant Garnault, who is at present on leave to Europe, will be thanked for his valuable and interesting report, and his exertions in making the investigations under great difficulties will be commended.

3. I am to state that, if the services of an Engineer Officer can be made available for the duty, the investigation will be continued during the next cold season, and it should comprise the valleys of the Burrakur and of all the main tributaries of it and of the Damoodah.

4. I am to observe that one thing is quite clear to the Lieutenant-Governor, that unless the project of constructing these reservoirs is taken up on a comprehensive scale, with a determination to carry it out at least to the extent indicated in Lieutenant Garnault's Report, it will be of little practicable benefit so far as mitigating the effects of floods is concerned. The four reservoirs recommended by Lieutenant Garnault on the Gurhee, Haharoo, Bakaroo, and Konaree Nuddes, and noticed in paragraphs 37 to 50 of his Report, would only have the effect, according to his calculation, of lowering the flood level one foot at Edilpore, and thereby diminishing by about one-half the damage heretofore done by inundating floods. To attempt less than this would be trifling with an object of great importance, and it is certainly desirable that a much greater measure of protection should, if practicable, be attained.

5. The Officer, who may be appointed to continue Lieutenant Garnault's investigations, should be requested to frame an estimate for the dams proposed by Lieutenant Garnault, and for any other

dams that may be recommended, and the necessary establishment should be placed at his disposal for the purpose. The estimate should include the cost of the land to be taken up for the reservoirs and for compensation for property.

No. 4012.

Copy of the above letter, and of the Memorandum and Report referred to, forwarded to the Government of India in the Public Works Department for information.

From the Government of Bengal, to LIEUTENANT H. W. GARNAULT, R. E.,
—(9th October 1866.)

Your Report No. A. dated the 24th June 1864, on the exploration of the upper reaches of the River Damoodah, having been under the consideration of the Lieutenant-Governor, I am desirous to convey His Honor's thanks for your valuable and interesting Report, and to commend your exertions in making the investigations under great difficulties.

From the Government of India, to the Government of Bengal,—(Simla,
13th October 1866.)

With reference to your docket No. 4012 dated 28th September 1866, I am directed to request that copies of the plans and sections alluded to in Lieutenant Garnault's Report on the exploration of the valley of the Damoodah may be furnished to this Office.

2. In connection with the scheme for the formation of reservoirs for the storage of the surplus waters of this river, and the intention to depute an Officer, if available, to complete the examination commenced by Lieutenant Garnault, I am to invite attention to Public Works Department Circular No. 25 of 1866 calling for proposals for employing establishments for preparing projects for irrigation works.

From the Government of Bengal, to the Government of India,—
(28th December 1866.)

With reference to your letter No. 934C. of 13th October last,
I am directed to submit the accompanying copies of the plans* and

* Nos. 742 to 746 of 1865-66.

sections illustrative of Lieutenant Garnault's Report on the exploration of the upper reaches of the Damoodah valley; and, with reference to the 2nd paragraph thereof, I am to intimate that Lieutenant J. M. Heywood, R. E., has been deputed by His Honor the Lieutenant-Governor to complete the exploration commenced by Lieutenant Garnault.

Circular from the Government of India, to the Government of Bengal,
—(22nd March 1866.)

Under instructions from the Secretary of State, the Government of India desires me to invite the attention of the Government of Bengal to the subject of the preparation of projects for Irrigation Works, such as would be the most proper to commence upon in the event of funds being made available within the next few years.

2. In determining which projects to select for survey and detailed estimate, it is desirable that two main objects should be kept in view. The first is to select those works first for execution which are calculated to prevent the occurrence or mitigate the severity of drought and famine; the second is that the works should be remunerative. No project should be selected which is not likely to satisfy both these conditions.

3. Amongst those which do satisfy both, preference should be given to those which are most urgently needed in respect to the first condition; and which are likely to be most rapidly and eminently profitable, as regards the second.

4. This latter condition is of immense importance in view to any general scheme for prosecuting Irrigation Works throughout India. It will be impossible to provide adequately for the outlay except under the prospect of an early and satisfactory return for the money, so that, ultimately, the necessary funds for the prosecution of fresh works shall be provided out of the profits of those previously completed. A judicious selection in this point of view is essential to success.

5. Further, it is to be borne in mind that any development of works must be gradual. Whatever scale of operations it may be possible ultimately to take up, it is obvious that, at first, there can only be a moderate extension of existing operations. The scale upon which

the preparation of detailed projects and estimates should be taken up must, therefore, be limited by the prospect of getting the works put in hand when the estimates are ready. It is impossible to lay down exactly at present what scale of outlay can be contemplated, but it will be safe, as an approximate guide, to say that no scheme of projects should be got up as yet which will require for execution an additional outlay of more than one-fourth of the present budget grant annually.

6. Some of the Governments and Administrations have already projects matured; others have made progress in the investigation of projects for irrigation works; others, again, may be able to get projects prepared by the establishments already employed, with some slight additional staff of Surveyors, &c.; others, again, may require the appointment of special officers with the necessary subordinates altogether in excess of existing establishments.

7. A review should be made of the projects completed and in progress, and of those to be selected for investigation; and the further steps to be taken should be limited by the prospect of providing under the above financial limit for the ultimate outlay required for carrying out the works. For whatever is thus decided upon as necessary to be further examined and estimated, the means in hand in the way of establishment should be considered, and, if necessary, application should be made to the Government of India for an addition of Engineers or Subordinate staff as may be needed.

8. With any such applications, the Government of India will expect to receive a full general review of the operations contemplated.

From the Government of Bengal, to the Government of India,—(8th February 1867.)

With reference to your Circular dated the 22nd March last, requesting the submission of projects for Irrigation Works in Bengal which might be commenced upon in the event of funds being made available within the next few years, I am directed by the Lieutenant-Governor to state as follows for the information of the Government of India.

2. The Lieutenant-Governor is unable at present to bring forward any detailed project for Irrigation Works in Bengal; but as there appears to be a prospect of funds being made available, and of the necessary Establishments for investigating projects being allowed, His Honor desires me to submit the following remarks and general proposals.

3. One of the best fields for irrigation in Bengal has been taken up by the East India Irrigation and Canal Company under their Orissa contract.

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*	*	*	*	*	*
*	*	*	*	*	*

6. Another extensive scheme has been brought forward by the East India Irrigation Company for irrigating a large portion of Behar from the River Sone, and has been accepted by the Government of India under conditions that have been agreed to by the Company.

7. It was the intention of the Lieutenant-Governor to have brought forward, as worthy of investigation, a general proposal originated by the late Lieutenant-Colonel Short, for a Canal from the left bank of the Damoodah, with the double object of providing irrigation for a populous part of the country and of facilitating the coal trade of Raneeunge and its vicinity: a proposal was, however, received for carrying out this project by means of a private Company to be formed, and this has received the cordial approval of the Lieutenant-Governor, whose opinion is strongly in favor of such works being undertaken by this description of agency, unless the Government is itself prepared to undertake them immediately and to provide funds and agency for their vigorous prosecution and speedy completion. The definite proposal for registration has not yet been received, but it is believed that the promoters still intend to carry out the project. Should the execution of this proposal through the means of private capital fail, the Lieutenant-Governor would wish it to be one of the first projects to be investigated by Government Officers.

8. Projects for a Canal from the right bank of the Damoodah to Midnapore have been brought forward on several occasions; but the want of establishment to prosecute enquiries, and the absence of any

prospect of the necessary funds being available, have hitherto prevented anything being done in regard to such projects. The waters of the Delkishore or Roopnarain, the Selye and the Subunreeka may also be made to contribute to the irrigation of parts of Burdwan, Hooghly, and Midnapore.

9. As the Government of India is aware, a general exploration of the upper part of the Damoodah was made by Lieutenant Garnault with the view of determining the feasibility of forming reservoirs to hold back the excess rain-fall during the rainy season and to augment the supply of water at other times of the year. An Officer is now employed in prosecuting these enquiries more fully for the purpose of fixing on the best places for reservoirs, and it would assist in disposing of the important question connected with these researches if the projects for Canals could be also brought under consideration at the same time, and these should therefore be amongst the first projects taken up.

10. It will be in the remembrance of the Government of India that the East India Irrigation and Canal Company proposed to extend their operations to the eastward of the original Behar scheme, and Colonel Rundall very ably urged the advantages of having a constant supply of water for the irrigation of these districts, such as could alone be drawn from the Sone, and he also represented the great assistance to trade that would arise from a navigable Canal connecting Behar with Calcutta, and affording a secure line of water communication at all seasons instead of the at times more dangerous route by the Ganges. This proposal was strongly recommended by the Lieutenant-Governor, and His Honor thinks that an investigation of the proposal should be made and the question more fully discussed in all its bearings. The investigation should embrace also the country between the Sone and the Kurumnassa, including the latter river and its tributaries beyond the limits of Colonel Dickens' project.

11. The districts of Chumparun and Tirhoot suffered much from drought during the past season, and it would appear that Irrigation Canals could be advantageously drawn off from the left bank of the River Gunduck and command a large tract of country in these districts. There are other rivers flowing from the Nepaul Hills, such as the Bagmuttee and Little Gunduck which might be made to subserve the same

purpose. This project would be of much importance for *prevention of distress, and should, the Lieutenant-Governor considers, be investigated.

12. It would also be advantageous if any Canal that the Government of the North-Western Provinces might take from the right bank of the Gunduck were extended to the southern portion of Sarun.

13. The River Teesta, which debouches from the Himalayan Range in the neighbourhood of Darjeeling, affords a large supply of water, which could no doubt be led down the water-shed of the country on the right bank, so as to command a large tract of land in the rich and populous districts of Rungpore, Dinagepore, and Rajshahye, which are now destitute of the means of irrigation, and the greater part of which has no outlet for its produce except during the rains.

14. Many other useful and profitable projects of irrigation could no doubt be brought forward in connection with the numerous streams which traverse the country lying between the Himalayas and the Ganges, especially the Kosi and Mahanunda; but information is wanting in regard to the capacity of these rivers, the extent to which their waters can be made available, and the levels of the country which they apparently command.

15. The peculiar features of Eastern Bengal render that part of the province less dependent than others on the means of artificial irrigation, and at the same time present greater difficulties than are to be found elsewhere. Something may no doubt be done by taking advantage of the periodical overflow of the rivers which traverse these districts to store up water in tanks, but the question as regards these districts is not of pressing importance.

16. In Assam the supply of labor is so insufficient for present requirements that it would perhaps seem needless to create new demands; but the wants of this fertile province in regard to works of Public Improvement are very great, and it is most desirable to have the circumstances of Assam thoroughly enquired into and its wants fully reported on.

17. The Government of India is aware that there exist at present remains of large works undertaken during the time of the Rajahs of

Assam before the conquest and occupation of the country by the Burmese. These were partly embankments and partly roads, that also facilitated irrigation and agriculture by controlling and confining the floods of the Berhampooter and its tributaries.

18. The Lieutenant-Governor would propose to have these old works thoroughly examined with the view of ascertaining their condition, their original purpose, and the manner in which this purpose has been fulfilled. The bearing of these works on the present wants of the province should also be considered, and whether it would be preferable wholly or partially to renovate them, or to undertake new works on a different system.

19. The order in which the Lieutenant-Governor would propose to take up the various projects is:—

* * * * * *

2nd,—Irrigation from the Rivers Damoodah, Delkishore, and Selye.

* * * * * *

21. The extent to which the works proposed for investigation may be remunerative cannot now be discussed for want of sufficient data, but the Lieutenant-Governor has no doubt that irrigation works properly designed and constructed in connexion with the rivers above-mentioned would be of very great utility and would eventually, perhaps in some cases speedily, yield a profitable return.

22. Referring to the other main object to be kept in view agreeably to your letter of instruction under acknowledgment, *viz.*, the selection of those works first for execution which are calculated to prevent the occurrence or to mitigate the severity of drought and famine, I am to remark that the Lieutenant-Governor would have placed the project for Canals north of the Ganges first in the list had it not been for the more forward state of the case and the other circumstances connected

with the Damoodah question, to which on the whole His *Honor would give the preference.

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*	*	*	*	*	*

EXTRACT of a Despatch from Secretary of State for India, dated 10th January 1867, circulated by Government of India, 21st March 1867.

“I am prepared to authorize the immediate commencement of any irrigation works that will satisfy the requirements specified in paragraph 9 of my Despatch in the Financial Department, dated August 23rd, 1866, (No. 200,) and I will sanction whatever financial arrangements may be necessary for prosecuting those works with vigour. The rapid completion of remunerative irrigation works, wherever the conditions necessary to their construction exist, is an object of the first importance. For the attainment of it, I must now rely upon the energy of the Governments of India in preparing the necessary plans, and carrying them out when they have been approved.”

From the Government of India, to the Government of Bengal,—(16th March 1867.)

I am directed to acknowledge receipt of your letter No. 5236 of 28th December last, submitting the plans and sections connected with Lieutenant Garnault's Report on the Damoodah, and reporting that the completion of the inquiry is being prosecuted under Lieutenant Heywood.

2. The Governor General in Council desires me to convey the approval of the Government of India to the prosecution of the inquiry, and to express concurrence in the commendation bestowed by the Lieutenant-Governor on Lieutenant Garnault's labors.

3. I am further to add that the Governor General in Council trusts that the surveys and levels may be so carried out as to admit of a portion of the project being ready for execution during the next working season.

4. To this end I am to observe that it is not necessary, nor even desirable, that the entire system of storage should be arranged for and settled before the works of irrigation are undertaken. So great an undertaking as that of controlling the floods by storage reservoirs can only be carried out gradually and experimentally, and to such extent as may be justifiable by the returns to be obtained by irrigation and navigation on the canals to be constructed in connection with the reservoirs. (*See* pages 120—21, Bengal Selections No. XV.)

5. But the works of irrigation and navigation may be undertaken at once on completion of the necessary surveys and estimates to such extent as there shall be water available in the river, or obtainable by a small and easily executed portion of the storage works.

6. A selection should therefore be made of a few of the most suitable sites for reservoirs, and detailed designs and estimates for them, together with designs and estimates for head-works and canals on both sides of the Damoodah, including one for navigation to connect Ranecgunge with the Hooghly, should be put in hand as speedily as possible; the necessary surveys and sections being at once proceeded with.

7. As it is understood that Lieutenant Heywood will proceed to England on leave in the course of this year, the Governor General in Council will endeavour to place the services of an Officer experienced in irrigation works at the disposal of the Bengal Government to complete the project.

8. In connexion with Mr. Schiller's proposal to construct a canal for navigation only from Ranecgunge to the Hooghly, I am directed to forward, for the information of the Lieutenant-Governor, copy of a correspondence with the Secretary of State; and to request that the view therein expressed may be kept in mind, in case of the promoters of the scheme being disposed to take further steps in the matter.

From the Government of India, to the Secretary of State for India,—(dated the 24th September 1866.)

We have the honor to forward, for the information of Her Majesty's Government, copies of the papers noted at foot, on the subject of a proposal put forward by certain gentlemen for the

construction of a canal to connect the coal-fields of Raneeunge with the River Hooghly.

2. It will be seen from these papers that the Government of Bengal suggested the advisability of combining irrigation with navigation in such a canal, but we have informed that Government that, while we are disposed to consider favorably any project for a navigable canal in this region, the question of making it an irrigable one also must depend in great measure on the views of Her Majesty's Government in regard to the agency by which works of irrigation should be undertaken.

3. It will be seen that we draw the attention of the Bengal Government to certain other points which we considered it desirable should be brought to the notice of the promoters of the present scheme.

From the Secretary of State for India in Council, to the Governor General of India in Council, —(No. 75, dated the 10th December 1866.)

I have had before me in Council your Excellency's Despatch No. 149 of 24th September last, relative to a proposal put forward by certain gentlemen for the construction of a navigable canal to connect the coal-fields of Ranceunge with the River Hooghly.

2. Except in one respect, your reply to this proposal appears to me to have been very suitable. The cost of the canal is, I observe, estimated at a million sterling, for the raising of which the promoters of the scheme think three years would be required to be followed by six years for the execution of the work. The prospect thus held out was too uncertain, as well as too remote to excite any very lively interest on your part; and as much countenance of the project as could reasonably be expected was given by the intimation that you would be glad to see it encouraged under Act XXII. of 1863, provided it should be found not to clash either with the interests of the East Indian Railway Company or with any prior claims of the East India Irrigation and Canal Company to the construction of canals in the same region. Your additional intimation, however, that permission to combine irrigation with navigation in the canal must depend greatly on the views of Her Majesty's Government in regard to the proper agency for constructing works of irrigation, appears to have been made under some

misapprehension. It seems to imply that some general rule is to be laid down as to the agency in question, and that, in the meantime, no proposals for the application of private enterprise to irrigation works can be entertained. I do not, however, see the advantage of any such rule. I readily admit that there are many reasons why it would be preferable for Government itself to provide completely for irrigation throughout India, if Government had adequate means at its command. But the requirements of India in respect of irrigation are so vast and so urgent that I cannot think it wise wholly to reject the assistance of private agency in supplying them. One material objection to the employment of such agency is the difficulty of fixing the water rent, if it is to bear any determinate ratio to the increased fertility conferred by irrigation upon the land. This difficulty will best be met by abandoning the attempt to establish any such ratio. The profit looked for by the Company who supply the water, and consequently the maximum price chargeable for it to the cultivator, should be proportioned to the cost of supplying it, and not to the increased return which the cultivator may, by its means, contrive to extract from his land. With this *proviso*, the proper course, whenever any irrigation project may come under consideration, would seem to be to decide upon the question of agency according to the merits of the particular case. If the project were one which appeared likely to be executed more rapidly or more satisfactorily by a Company than by the State, a Company might be entrusted with it. If no Company equal to the undertaking presented itself, or if there were special objections to the intervention of a Company in the particular instance, or if Government had at the time sufficient means readily available, Government agency would naturally be preferred. But nothing should, in my opinion, be done to hamper in any way Government's perfect freedom of choice. A general rule could scarcely be devised for ever varying circumstances, which would not be continually proving itself inapplicable.

From the Governor General of India in Council, to the Secretary of State for India,—(No. 40, dated the 16th March 1867.)

We have the honor to acknowledge receipt of Lord Cranborne's Despatch No. 75 of the 10th December last, on the subject of a proposal by Mr. Schiller and other gentlemen to construct a navigable canal from the coal-fields of Raneegunge to the Hooghly, near Calcutta.

2. We learn with satisfaction that the reply we have caused to be made to the Government of Bengal on this subject is approved in the main. On one point, however, it is thought that we have written under some misapprehension of the intentions of Her Majesty's Government as apparently understanding that it was desired that the employment of private agency for constructing irrigation works should be altogether discontinued in case of funds being made available for carrying out works of irrigation by the agency of the Government Engineers. It will perhaps not be necessary for us to enter here upon this general question, since our reference to the matter of the prosecution of works of irrigation by Government agency was made solely in regard to the individual case.

3. It has been long in contemplation to construct works of irrigation from the Damoodah, and the question is connected with the formation of reservoirs in the upper reaches of that river and other measures for controlling the floods. The works of irrigation being connected with these arrangements would probably not be very remunerative, while, in order to enable us to carry them out without burdening the general revenues with a large expense, it is most desirable that we should retain in the hands of Government all the profits that can be realized from the works. A very large and important part of the profits of such works would be from the very navigation to which the promoters of the canal scheme now under consideration look. It appeared to us therefore, that, in the event of sanction being given to the prosecution of the works of irrigation by the agency of the Government itself, a private Company should not be allowed to carry out this canal. Hence the reservation we made.

4. If a private Company were allowed to undertake the entire project, it would doubtless carry out first the most profitable parts of it, and we should fail to realize the advantages to the country we expect in the combination of storage operations for the control of the floods with the works of irrigation and navigation.

5. We now proceed to explain more in detail the nature of the project we have had in contemplation and the steps taken in regard to it.

6. The floods of the Damoodah have been for years a source of trouble. The Government had long ago entered into agreements with the Zemindars to keep up the embankments. Year after year the embankments were repaired, and year after they were breached. The floods let suddenly on the land, after being for a time held up by the embankments, were more disastrous than if they had spread quietly over the country from the first. At last, in 1851, Colonel Beadle (then Lieutenant) suggested that the Government was attempting an impossibility, and that the lower channels of the river would not carry off between the embankments the volume of water which in floods poured down from the upper course of the river. Surveys were made and levels taken, and on these being submitted to calculation,* it was proved that Colonel Beadle's notion was correct, and that no practicable height of embankments, and no practicable width of channel left between the embankments, would suffice to carry off the floods. And, ultimately, the Government adopted his proposal to throw down the embankments of the right bank of the river, in order to save the country on the left from flood.†

* Bengal Selections from official records No. XV., pages 120 and 121.

† Bengal Selections No. XL., pages 2e. to 12.

7. No breach has ever occurred in the embankments of the left bank since. The measure has therefore been so far a perfect success. But it was further a question whether the country on the right bank had suffered in consequence of the removal of the embankments. The result of the last enquiries on this subject was to satisfy the Lieutenant-Governor of Bengal that there was a considerable amount of damage to the land, and even misery to the people in the tract thrown open to the inundations, though it is still doubtful whether, on the whole, it may not have benefited.

8. His Honor therefore decided that the Public Works Department should undertake an inquiry regarding the upper basin of the Damoodah, to see whether it might not be possible to store the water in reservoirs, so as not only to stop the floods, but to obtain the use of the water for irrigation in the dry season. This measure had been suggested in 1853† as the only completely satisfactory means of

† Bengal Selections No. XV., page 120.

removing the evils which the floods produced. * Its practicability, however, must depend upon the possibility of utilizing the water for irrigation and getting it paid for accordingly ; for the expense of the storing must be so great that it would be out of the question to incur it except on the prospect of an adequate return.

9. About the time the Government of Bengal resolved to make the investigation, the East India Irrigation Company had commenced its inquiries, and, at the suggestion of the Agent, the Lieutenant-Governor of Bengal proposed to withdraw from the field and leave the inquiry to the Engineers of that Company. This the Government of India objected to, and ordered the inquiry to be prosecuted by the Government Engineers. This was reported to Her Majesty's Government in our Despatch No. 74 of 5th November 1863, and approved in Sir C. Wood's No. 5 of 9th February 1864.

10. The enquiry was accordingly commenced by Lieutenant Garnault, R. E. Circumstances, however, prevented that Officer from devoting more than two-and-a-half months to the object, and of course it was not to be expected that any very satisfactory result could be attained in that time. Lieutenant Garnault, however, established the practicability of constructing four reservoirs to contain about one-fifth of the water which he calculates it is necessary to store in order to fully control the floods.

11. His report was received in October last without the plans. As no authority had been received for raising money to carry on works of irrigation, the matter had not been considered urgent by the Bengal Government. But when the report reached us, the prospect of constructing irrigation works had become more settled under Lord Halifax's Despatch No. 266 of 30th November 1865, and, with reference to the concluding sentence of paragraph 13 of that Despatch, the attention of the Bengal Government was drawn to the necessity for completing the survey in connection with the orders we had issued for pushing on the preparation of irrigation projects.

12. The plans have now been submitted by the Bengal Government, with an intimation that Lieutenant Heywood, R. E., has been deputed to complete the investigation. Lieutenant Garnault has been

obliged to go to England on sick leave, it is believed, owing to fever contracted during his survey.

13. We have now further instructed the Government of Bengal to prosecute the survey vigorously, and to have some portion of the project ready for execution by the next cold season. A copy of our orders and previous proceedings are submitted.

From the Government of Bengal, to MESSRS. GOODENOUGH, PETERSON,
AND SCHILLER,—(3rd May 1867.)

In continuation of my letters No. 3483 dated the 27th

Letter from Government of India No. 347, dated 16th March 1867, enclosing letter No. 149 dated the 24th September 1866 from that Government to Secretary of State.

Letter No. 75 dated the 10th December 1866 from the Secretary of State to Government of India.

Letter No. 40 dated the 16th March 1867 from Government of India to Secretary of State.

August and No. 4014 dated 29th September last, I am directed by the Lieutenant-Governor to forward to you a copy of the further correspondence marginally noted.

From the Government of Bengal, to Officiating Superintending Engineer, Presidency Circle,—(3rd May 1867.)

With reference to my letter No. 4011 dated the 28th September last and previous correspondence relative to the construction of reservoirs for controlling the floods of the Damoodah, and of a canal to connect Raneegeunge with the River Hooghly, I am directed by the Lieutenant-Governor to forward herewith a copy of a letter No. 347 of the 16th March last, received from the Secretary to the Government of India, Public Works Department; and to state that a copy of this letter will be forwarded direct to Lieutenant Heywood, with instructions to prepare his report, as far as possible, so as to meet the wishes of the Government of India, as expressed in paragraphs 3, 4, 5, and 6.

2. An Officer to carry on the work will also be appointed before the cold season; meanwhile, if it is possible for you to help on the work in any way, as by keeping registers of rain-fall, observing floods, &c., you are requested to do so.

Copy forwarded to Lieutenant J. M. Heywood, R. E., for information and guidance, and with the request that he will prepare and submit his report as soon as possible.

Copy of a Despatch from Secretary of State dated 31st May 1867 forwarded by Government of India to the Government of Bengal on the 8th July 1867, with a request that the whole matter may be brought prominently to LIEUTENANT-COLONEL RUNDALL'S notice, on his assuming charge of the Irrigation Department under that Government:—

"I have received and considered in Council your Despatch (No. 40) dated 16th March 1867, on the subject of the contemplated works for controlling the floods of the Damoodah River, and for the formation, in connection therewith, of a Canal for irrigation and navigation.

2. The interesting report of Lieutenant Garnault has established the practicability of forming reservoirs on the head waters of the Damoodah, and of thereby lowering the level of the floods more than one foot, thus alleviating the injury done to the tract on the right bank of the river by the inundations to a very considerable extent. It seems very desirable that these works should be commenced as soon as possible, provided that there is sufficient assurance that the water can be made available for irrigation, and I am glad to perceive that you have ordered the survey to be hastened, so that some portion of the project may be ready for execution this year.

3. Your reasons for declining the offer of Mr. Schiller to construct a navigable Canal from the coal-fields of Raneegunge to the Hooghly, as applied to this individual case, appear to me to be perfectly sound."

Orders by the Government of India, dated Simla, the 20th August 1867, on the recommendations of the Commissioners on the Famine of 1866 in Bengal and Orissa.

READ—

Report of the Commissioners appointed to enquire into the Famine.

RESOLUTION.—The recommendations of the Commissioners relating to matters connected with the Public Works Department have been

considered by the Governor General in Council separately under the following heads :—

I.—Measures relating to Orissa specially.

*	*	*	*	*	*
*	*	*	*	*	*
*	*	*	*	*	*
*	*	*	*	*	*
*	*	*	*	*	*
*	*	*	*	*	*

II.—Projects beyond Orissa.

* * * *

10. The utilization of the waters of the Damoodah and neighbouring rivers, and the formation of reservoirs on the hills west of Bengal, have already long engaged the attention of the Governments of Bengal and of India, and Reports from Lieutenants Garnault and Heywood, of Royal Engineers, have been received; but now that a Chief Engineer of Irrigation for Bengal has been appointed, the subject should at once be taken up and dealt with more vigorously and systematically than hitherto.

*	*	*	*	*	*
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*	*	*	*	*	*
*	*	*	*	*	*
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Report by LIEUTENANT J. M. HEYWOOD, R. E., of the result of his investigation of the Upper Damoodah, submitted to Government on 11th September 1867.

In accordance with instructions received from the Chief Engineer and Colonel Short, (late Superintending Engineer, Presidency Circle,) I proceeded in October 1866 to Hazareebaugh to continue the examination of the upper reaches of the Damoodah and its tributaries, which had been commenced by Lieutenant Garnault.

2. The object in view being to discover sites suitable for reservoirs to keep back the inundating floods and store the excess water for future use, either to irrigate the neighbouring land or increase the

available flow of the lower Damoodah during the dry season, and thus form a source of supply for canals, and it being impossible to present a complete scheme without a thorough examination of the whole district, (7,000 square miles,) I determined to visit every affluent of the main Rivers,—Damoodah and Burrakur,—and not to delay on any one till this was accomplished. I was able to move into camp on the 2nd November, and continued the exploration of the upper reaches of the Damoodah till the end of December.

3. During January and February I was engaged on the Burrakur, and for the greater portion of March on that part of the Damoodah between the Jumoonah and Burrakur Rivers. Towards the end of March I was compelled to give up survey work and proceed to Calcutta. In that time I levelled about 233 miles, and visited every affluent of any size both on the Damoodah and Burrakur to the north of their junction.

4. The two Sub-Overseers sent from Calcutta to assist me joined my camp at the end of December and were wholly employed on a detailed survey of the site of the proposed reservoir at Burhee. They were unskilled in the use of the survey instruments and were only able to complete that single work.

5. I found 14 sites more or less suitable for reservoirs, which, with the four discovered by Lieutenant Garnault, gives a total of 18. A description of each will be given in a subsequent portion of this Report.

6. The data necessary to arrive at correct conclusions as to the amount of water to be stored up are doubtful, and the calculations can only be considered approximations; but, as I have always taken the higher quantities, no mistake of any importance can occur.

7. The rain-fall in and near the catchment basin has been noted at Calcutta, Burdwan, Bancoorah, Sooree, Hazareebaugh, and Ranchee, with the exception of Sooree (the return from which place has not reached me). I have been able to procure copies of the monthly fall at all these places for the eight years ending December 1866.

8. At Hazareebaugh, both the Civil Surgeon and Executive Engineer keep rain gauges, but the differences in their Registers are too

great to render them of any use as checks upon one another. I have therefore, in the following calculations, used the one giving the highest results.

9. The mean yearly rain-fall at Calcutta is 69·57 inches.

Burdwan	59·88	„
Bancoorah	54·70	„
Hazareebaugh	75·52	„
Ranchee	39·28	„

showing a very considerable and progressive decrease towards the source of the river, except where the Hazareebaugh plateau intervenes. The precipitation of rain on this portion of the basin is only locally excessive, as Ranchee, situated on ground as elevated as the station of Hazareebaugh, only receives 39·28 inches, or little more than half.

10. The determination of the mean rain-fall over the whole of the catchment basin cannot be exactly made, owing to the paucity of the places where gauges have been kept, but the nature of the country where they have been noted will be a valuable guide.

11. Hazareebaugh is situated on an undulating plateau 2,000 feet in height. This, however, extends over a very limited extent of ground, as nine miles to the north of the station it drops suddenly 500 feet, and 10 miles to the south-west about 650 feet. On the south-east side the slope is more gradual, the fall being about 730 feet in 30 miles. I consider, therefore, that it will be an outside estimate if I assume 900 square miles as the area of this plateau above the height of 1200 feet.

12. To the south of the plateau, from the source of the Damoodah to the junction of its affluent, the Gurgree Nuddee, or an area of 2,100 square miles, a mean between the rain-fall at Hazareebaugh and Ranchee will probably be the most correct; and to the junction of the Burrakur, or 1,200 square miles, the observations made at Bancoorah will supply the most reliable data.

13. The basin drained by the Burrakur, or 2,700 square miles may be considered as affected about equally by the rain-fall at Hazareebaugh and Bancoorah.

14. The mean yearly rain-fall on these suppositions will be 62·314 inches, and during the years—

1860	39·55 inches
1861	61·97 „
1862	73·65 „
1863	72·79 „
1864	40·61 „
1865	65·85 „
1866	77·18 ..

15. The greatest monthly rain-fall occurred at—

Hazareebaugh in August 1862, and amounted to 31·13 inches.

Ranchee	in July	1864,	„	to 16·90	„
Bancoorah	in July	1862,	„	to 22·10	„
Burdwan	in July	1861,	„	to 24·95	„
Calcutta	in June	1861,	„	to 26·44	„

16. The greatest daily rain-fall noted since 1858 was—

At Hazareebaugh 13 inches on the 25th September 1863.

„ Bancoorah	9·20	„	„	22nd „	1860.
„ Burdwan	8·70	„	„	26th October	1858.
„ Calcutta	4·20	„	„	2nd July	1866.

17. The water thus precipitated in the form of rain either drains off the surface of the ground at once, disappears by evaporation, or sinks into the ground. In the latter case, a portion eventually flows off into the natural discharge channels, a portion sinks to the subsoil and remains there, and the remainder is absorbed in nourishing the rank vegetation which covers the whole of the basin.

18. The quantity of water taken off by evaporation during the entire year, whether from the surface of the streams, tanks, &c., or from the moist soil, must be very large, though during the heavy floods the amount removed may be small.

19. The following table gives the result of a set of experiments conducted at Burdwan in the years 1861 to 1866 inclusive :—

DATE.	1861.			1862.			1863.			1864.			1865.			1866.			
Month.	EVAPORATION.		Rain-fall.	EVAPORATION.		Rain-fall.	EVAPORATION.		Rain-fall.	EVAPORATION.		Rain-fall.	EVAPORATION.		Rain-fall.	EVAPORATION.		Rain-fall.	
	Tank.	Cistern.		Tank.	Cistern.		Tank.	Cistern.		Tank.	Cistern.		Tank.	Cistern.		Tank.	Cistern.		Tank.	Cistern.
Jan. ...	Incomplete.	Incomplete.	0.00	8.30	4.80	0.20	7.10	3.90	0.00	8.20	5.00	0.00	8.10	5.00	0.00	11.30	Incomplete.	1.75	
Feb. ...			0.00	8.80	4.50	0.00	6.70	4.30	0.50	7.70	2.90	1.20	6.40	4.10	3.30	7.00		6.65	
March...			0.10	10.00	5.60	0.70	13.50	8.10	0.00	9.40	4.60	0.70	8.60	5.50	1.80	13.00		0.60	
April ...			0.70	10.10	6.30	3.50	10.86	6.40	1.65	9.90	5.60	0.70	8.00	5.30	2.10	8.60		2.70	
May ...	7.70	5.55	5.80	8.50	5.20	4.40	7.30	2.40	4.45	9.80	5.30	5.90	5.20	3.20	13.85	6.90		2.10	
June ...	3.70	5.60	15.80	6.30	2.90	8.95	3.50	0.70	11.50	6.20	3.00	6.15	5.80	3.50	7.90	2.60		13.85	
July ...	2.90	3.60	24.95	1.70	1.20	18.65	3.90	3.10	8.80	1.00	0.80	14.25	3.60	2.40	13.05	1.20		14.80	
August..	6.20	1.80	7.20	5.30	3.10	5.85	2.20	0.90	15.30	2.10	1.40	10.20	5.70	3.80	5.80	Incomplete.		12.80	
Sept. ...	6.60	7.70	17.90	4.40	2.80	7.75	6.60	4.20	4.95	4.00	2.50	4.00	5.45	3.70	7.97			6.20	
Oct. ...	12.00	6.10	11.20	6.00	3.60	12.65	7.80	4.90	2.00	2.70	1.90	0.80	5.20	3.20	0.00	Incomplete.		2.20	
Nov. ...	9.90	4.20	1.30	8.40	5.40	0.00	9.40	5.70	0.30	7.10	4.30	0.50	9.30	Incomplete.				0.00	
Dec. ...	8.80	4.70	0.35	8.10	5.60	0.00	9.10	5.55	0.00	8.50	4.80	0.00	11.80					0.00	Incomplete.				0.00
Grand Total.	57.80	39.25	85.30	85.90	51.00	62.65	87.90	50.15	49.45	76.60	42.10	44.40	83.15	39.70	56.05	50.60		63.65	

20. The number of days on which rain fell was as follows :—

Month.	1861.	1862.	1863.	1864.	1865.	1866.	REMARKS.
January	1	3	Rain-fall at <i>Burdwan</i> .
February ... ..	...	...	1	1	4	7
March ... ..	...	2	...	1	2	1
April ... ..	...	4	5	1	3	5
May... ..	13	9	9	8	11	4	
June	12	11	20	6	8	16	* This is, I think, incorrect.
July... ..	18	21	14	20	19	16	
August	13	13	19	14	12	25	
September	16	15	10	10	12	15	
October	8	11	7	1	...	1*	
November	4	...	1	1	...	...
December	1	1	...	...	1	...
Total ...	85	78	86	63	72	103	

21. Combining these tables, we obtain the following :—

DURATION OF TIME.	1860-61.			1861-62.			1862-63.			1863-64.			1864-65.		
	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.
$\frac{1}{2}$ October, November, December, January, February, and $\frac{1}{2}$ March ... }					24'50	0'17		24'70	0'17		24'85	0'168		22'00	0'153
$\frac{1}{2}$ March, April, May and $\frac{1}{2}$ June ... }					18'80	0'22		22'13'50	0'19		14'70	0'19		13'20	0'19
$\frac{1}{2}$ June, July, August, September, and $\frac{1}{2}$ October	57'19'50	0'30		9'30	0'166		10'80	0'177	45	5'84	0'075*		46'15'10	0'198	

* Incomplete.

A. being the number of days on which rain fell.

B. „ „ of inches of water evaporated from the cistern.

C. „ the amount evaporated on each day on which no rain fell.

From this last column, it appears that about 0'17 inches will represent the daily amount removed by evaporation on dry days throughout the year.

22. I have not sufficient data to compare the number of rainy days in different portions of the basin, but from the following Table I conclude that they occur less frequently at the source :—

Name of Month.			1863.			1866.			REMARKS.
			Burdwan.	Bancoorah.	Hazareebaugh.	Burdwan.	Bancoorah.	Hazareebaugh.	
January	..	..	0	...	...	3	2	...	
February	..	..	1	...	...	7	3	...	
March	..	..	0	...	...	1	1	...	
April	..	..	5	...	...	5	4	...	
May	..	..	9	...	...	4	2	...	
June	..	..	20	13	10	16	12	10	
July	..	..	14	12	19	16	13	20	
August	..	..	19	17	11	25	19	26	
September	..	..	10	11	13	15	12	12	
October	..	..	7	4	...	1	2	...	
November	..	..	1	...	...	0	0	...	
December	..	..	0	...	...	0	0	...	
Rainy days from June to September	..	..	63	53	53	72	56	68	
Rainy days from January to May and October to December	..	..	23	...	...	21	14	...	

Mean number of rainy days from June to September at Burdwan ... $67\frac{1}{2}$

Ditto ditto ditto at Bancoorah... $54\frac{1}{2}$

Ditto ditto ditto at Hazareebaugh $60\frac{1}{2}$

23. The difference would, however, only slightly affect the coefficient 0.17" which may be safely used as the measure of evaporation over the whole basin under the conditions mentioned in paragraph 21.

24. Evaporation removes water with greater rapidity from moist soil than from stagnant water. Lieutenant Ludlow made a series of

experiments on this point at the Madras Observatory, from which I extract the results noted on the four days of greatest rain-fall,—

On the 10th June	1844	..	1·635"	of rain fell
„ 17th „	„	..	2·548"	„ „
„ 7th July	„	..	2·335"	„ „
„ 6th August	„	..	1·808"	„ „

The proportion between the amount evaporated from saturated soil and from the water surface was—

1·303 : 1

1·096 : 1

1·120 : 1

1·231 : 1 or a mean of 1·187 : 1 between $\frac{1}{5}$ or $\frac{1}{6}$ more.

This being the case, the daily depth of water removed would equal ·2018".

25. Experiments made in Europe give different results to this, but they vary so much as to afford no guide.

26. Assuming, therefore, that the figures above are correct, and adopting the following suppositions,—

1st,—That $\frac{1}{3}$ rd of the basin is annually under rice cultivation ;

2nd,—That from the middle of June to the middle of October this $\frac{1}{3}$ rd part is under water ;

3rd,—That after each day of rain the whole basin is saturated for one day ; and combining the fact that from the 15th of June to the 15th of October the number of rainy days is 54, and consequently of dry days 68, and from the 15th of October to the 15th June, $23\frac{1}{2}$ and $219\frac{1}{2}$ respectively, I deduce the following,—

1st,—That the water evaporated from $\frac{1}{3}$ rd of the basin during the rainy season = 11·64 inches.

2nd,—Ditto ditto for the remainder of the year = 4·64 „

3rd,—That the water evaporated from the other $\frac{2}{3}$ ds of the basin during the rainy season = 13·82 „

4th,—Ditto ditto for the remainder of the year... = 4·64 „

or a mean for the whole basin per annum of 17·70 inches.

27. Evaporation, however, depends so much on the temperature of the land or the force and direction of winds, on the clear and electric state of the air, on the nature of the soil and cultivation, it having a maximum intensity on a naked soil, and a minimum where the ground is covered with woods, &c., that any calculation of its amount can only be considered as a guess. I have, however, considered it right to try and make an approximation.

28. The quantity of water which drains off the surface of the ground direct into the river, or subsequently finds its way there through the subsoil, &c., can be more accurately determined.

29. From a section taken by Lieutenant Garnault across the Damoodah at Raneegunge, I have prepared the table below :—

Height on Gauge.		Discharge in cubic feet per section.	Area in superficial feet.	Slope of bed.	REMARKS.
1	Foot	35	4·09	The slope was not entered on the section, but calculating backwards from the discharge at 19·29', or 343 657·48 cubic feet per section, I make it 4·09'.
2	Feet	344	.....	"
3	"	1,519	626·5	"	
4	"	4,835	1,402	"	
5	"	8,093	2,737	"	
6	"	18,775	4,804	"	
7	"	31,754	6,838	"	
8	"	47,321	8,937	"	
9	"	64,856	11,046	"	
10	"	84,169	13,165	"	
11	"	105,130	15,295	"	
12	"	127,580	17,434	"	
13	"	151,510	19,584	"	
14	"	176,800	21,744	"	
15	"	203,360	23,914	"	
16	"	233,311	{ 26,121·28 660·89 }	{ } "	
17	"	265,341	{ 28,311·63 1,348·90 }	{ } "	
18	"	296,265	{ 30,530·69 2,119·14 }	{ } "	
19	"	331,861	{ 32,821·67 3,049·60 }	{ } "	
19·29	"	343,657·48	

30. The discharge in cubic feet per second of the River Damoodah at Raneegunge for every day from the 1st of June 1860 to the 31st of December 1866 has been computed by the aid of this table and of those entered on the following pages,* which latter are extracted from the gauge registers kept in the Burdwan Office.

31. The comparison between the quantity of water shed off and the rain-fall has been determined from the table below, which has been worked out in accordance with the rules laid down in paragraphs 11 to 13.

Name of month.	1860.	1861.	1862.	1863.	1864.	1865.	1866.
January ..	0·000	0·2448	0·387	0·0718	0·000	0·529	1·210
February ..	0·494	0·000	0·000	0·000	0·127	1·307	4·630
March ..	0·369	0·1317	0·364	0·000	0·410	3·246	0·652
April ..	0·782	0·1635	0·997	0·147	0·850	3·026	2·855
May ..	0·2741	2·780	0·997	2·165	2·937	10·113	0·682
June ..	4·114	6·950	12·400	12·904	7·710	9·513	14·757
July ..	13·900	18·471	24·300	21·000	11·900	21·503	18·141
August ..	12·117	7·624	19·480	13·277	8·762	8·873	15·518
September ..	4·620	12·861	5·865	17·864	5·223	7·284	14·020
October ..	2·880	11·334	8·860	4·294	1·540	0·1847	4·573
November ..	0·000	1·082	0·000	0·147	1·152	0·240	0·140
December ..	0·000	0·328	0·000	0·573	0·000	0·000	0·000

* See Appendix I. at the end of this volume.

32. Remembering that 1 inch of rain-fall equals 2,323, 200 cubic feet of water per square mile, and that the area drained is about 7,000 square miles, the numbering of inches of rain shed off is as follows:—

Month.	1860.	1861.	1862.	1863.	1864.	1865.	1866.
January ..	...	0·001	0·2207	0·577	0·2365	0·2508	0·0408
February ..	...	0·006	0·074	0·310	0·2128	0·4362	0·4501
March ..	...	0·008	0·175	0·1477	0·1219	1·1618	0·0312
April ..	...	0·0009	0·0215	0·12·8	0·033	1·1946	0·3828
May ..	...	0·6189	0·227	0·4991	0·1315	4·808	0·4062
June ..	...	5·857	4·4509	4·8589	1·4957	4·665	4·2112
July ..	8·961	10·812	16·844	10·700	8·7367	10·955	10·2100
August ..	7·143	6·288	13·448	8·513	11·133	8·832	19·4630
September	1·969	13·039	6·481	10·518	7·8715	8·7078	12·7540
October ..	0·542	12·359	9·528	7·827	1·3054	0·345	4·9693
November	0·004	0·921	1·424	0·886	0·9263	0·066	1·0282
December..	0·001	0·465	0·758	0·402	0·3925	0·0467	0·2122
Total ..	18·62	50·403	53·655	45·369	32·5968	41·4693	54·160

and comparing these with the rain-fall the results are—

YEAR.				Inches of rain-fall.	Inches drained off.	Proportion of rain-fall drained off.
1860	..	..	..	33·517	18·622	·5556
1861	..	..	..	61·97	50·403	·8132
1862	..	..	..	73·65	53·655	·7285
1863	..	..	...	72·795	45·369	·6233
1864	..	..	..	40·61	32·596	·8027
1865	..	..	..	65·85	41·469	·6297
1866	...	..	..	77·178	54·160	·7017
Mean	..	..	..	.....	.....	·6929

viz., nearly $\frac{7}{10}$ of the whole yearly rain passes off through the drainage

channels, and this applies also to those portions of the year in which the heaviest rain falls.

MONTH.	Year.	Rain-fall.	Inches drained off.	Proportion of rain-fall drained off.	REMARKS.
June, July, August, and September	1861	45.906	36.027	.7848	
Ditto ditto ..	1862	62.045	41.221	.6644	
Ditto ditto ...	1863	65.045	34.5899	.5318	
Ditto ditto ..	1864	33.595	29.2369	.8704	
Ditto ditto ..	1865	47.173	33.1598	.7029	
Ditto ditto ..	1866	64.436	46.6382	.7471	
July, August, and Sep- tember	1860	30.637	18.073	.595	
Mean .. ..	...	...	...	.6994	

The maximum rain-fall occurred in July 1862, the amount having been 24.30 inches, and the proportion drained off was nearly equal to $\frac{7}{10}$ ths.

33. The drainage which separately passes down the upper Damoodah and Burrakur can only be determined approximately, as the only continuous gauge readings recorded in either of these rivers are those noted on the latter during the rains of 1866.

34. From three sections taken, one at the site of the new bridge across the Burrakur, near Taldargo, the second immediately below, and the third 2 miles further down, I find the highest discharge in cubic feet per section to have been 132,540 cubic feet.

	144,169	„	„
	143,450	„	„
Mean	...	140,153	

35. From the first section I have prepared the following table

Height above bed.	Area.	Discharge cubic feet per Section.	REMARKS.
Fect.			
1	102.3	241	
2	{ 259.3 161.72 }	1,231	
3	{ 580.3 355.87 }	3,160	
4	{ 877.00 594.50 }	5,560	
5	2334.75	10,530	
6	3187.75	16,445	
7	4023.70	22,824	
8	500.895	31,062	
9	6308.85	44,091	
10	7469.05	52,118	
11	8363.90	60,577	
12	9517.27	72,933	
13	11027.53	78,691	
14	12592.2	92,591	
15	14606.04	112,280	
16½	16453.85	132,540	

1866.

(59)

Month.	Date.	Height of water above bed in June.							Height of water above bed in July.							Height of water above bed in August.							Height of water above bed in September.											
		7 A.	M.	2 P.	M.	4 P.	M.	7 P.	M.	7 A.	M.	2 P.	M.	4 P.	M.	7 P.	M.	7 A.	M.	2 P.	M.	4 P.	M.	7 P.	M.	7 A.	M.	2 P.	M.	4 P.	M.	7 P.	M.	
June, July, August, and September 1866	1st	...	...	...	...	...	...	...	12:00	12:58	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	2nd	...	...	...	...	...	...	...	13:01	13:58	15:50	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	3rd	...	...	...	...	...	...	...	10:75	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	4th	...	...	...	...	...	...	...	7:41	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	5th	...	...	...	...	...	...	...	6:00	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	6th	...	...	...	...	...	...	...	5:41	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	7th	...	...	...	...	...	...	...	4:83	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	8th	...	...	...	...	...	...	...	4:16	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	9th	...	...	...	...	...	...	...	3:50	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	10th	...	...	...	...	...	...	...	2:75	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	11th	...	...	...	...	...	...	...	6:66	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	12th	...	...	...	...	...	...	...	6:33	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	13th	...	...	...	...	...	...	...	5:68	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	14th	...	...	...	...	...	...	...	4:50	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	15th	...	...	...	...	...	...	...	4:75	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	16th	...	...	...	...	...	...	...	3:66	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	17th	...	...	...	...	...	...	...	8:00	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	18th	...	...	...	...	...	...	...	6:16	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	19th	...	...	...	...	...	...	...	5:33	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	20th	...	...	...	...	...	...	...	6:50	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	21st	...	...	...	...	...	...	...	5:34	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	22nd	...	...	...	...	...	...	...	5:67	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	23rd	...	...	...	...	...	...	...	6:25	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	24th	...	...	...	...	...	...	...	10:58	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	25th	...	...	...	...	...	...	...	7:59	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	26th	...	...	...	...	...	...	...	6:75	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	27th	...	...	...	...	...	...	...	5:25	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	28th	...	...	...	...	...	...	...	5:59	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

36. Dividing these totals by 2,323,200 \times (area of basin in square miles) 2,700, and comparing the results with the rain-fall, we have—

MONTH.	Inches drain- ed off per square mile.	Inches of rain.	Proportion drained off.
June 18th to 30th ...	3.4861	14.20	.2454
July ...	7.4861	19.00	.3940
August ...	10.8580	16.55	.6560
September 1st to 20th ...	7.7988	11.48	.6793
Mean ...	29.629	61.23	.4936

or a little less than $\frac{1}{2}$ of the rain-fall is carried off by the river, but the experiments are too limited in number to draw correct conclusions from, and therefore I shall assume that $\frac{2}{7}$ ths of the rain-fall is the mean quantity which flows off the basin, both of the Upper Damoodah and Burrakur. This gives a depth of 43.1698 inches per annum, and, as according to previous calculations, 17.7000 inches represent the amount evaporated, the total 60.8698 subtracted from the mean rain-fall 62.314, or 1.4442 inches, will be the remainder which percolates through the soil, or is taken up to sustain vegetable life, &c.

37. Infiltration depends so entirely on the permeability or impermeability of the soil, and this varies to such an extent in the 7000 square miles of area forming the basin under consideration as to render it quite impossible to check the calculation I have given above.

38. Mr. Oldham in a communication addressed to me writes:—
“The permeability of the rocks varies most materially in different parts of the same basin. The Rivers Damoodah and Burrakur both flow in parts of their course through rocks of vastly different texture and character, the open free sandstones and pebble beds of the “coal measures” absorb and retain a very much larger amount of water than do the closer and harder beds of gneiss, and this rule is general, notwithstanding that you will find among the latter open and very porous beds, and among the former stiff clays, which are almost entirely impermeable.”

39. The proportion of water taken up to nourish vegetable life is still further removed from the field of accurate calculation, but there is no doubt whatever that large quantities are absorbed by the roots of trees, &c., and transpired from the leaves, &c., in every portion of the basin.

40. To complete the required data, it becomes necessary to examine the phenomena connected with those great floods of which observations have been recorded.

41. These have been noted at various places, the principal ones being Raneegunge and Edilpore; the former is situated at a point where the whole body of the drainage water passes down in the channel; the latter, nearly where the overflow commences: a rise of 10 feet on the Edilpore gauge shows that the bank is topped.

42. In 1857 the highest flood occurred on the 24th August, on which date the rise at Edilpore was 13 feet.

On August 22nd the gauge reading was 7 feet.

„	„	23rd	„	„	„	9½	„
„	„	24th	„	„	„	13	„
„	„	25th	„	„	„	12	„
„	„	26th	„	„	„	7½	„

Between the 23rd and 24th the river rose 3½ feet in 24 hours, so that during 20½ hours it was above its bank; this continued till the 25th, and between the 25th and 26th for about 10½ hours, giving a total of nearly 2 days and 7 hours for the time it was above safe level.

No estimate of the volume passed off can be given for this flood or those of 1858 and 1859 in consequence of the absence of readings at Raneegunge.

43. In 1858 the Damoodah did not rise above its banks at Edilpore; but in 1859, on the 28th July, a most destructive flood occurred, the gauge reading at Raneegunge being 18' and at Edilpore 14' 6".

Mr. Smith, the Executive Engineer of Burdwan, thus described it:—"At Edilpore the river commenced rising from a level of 5 feet

very early in the morning of the 28th of July, and at noon attained its greatest height level of 14' 6", which it maintained for 3 hours. At 3 o'clock P. M. it began to subside, and fell one foot by 6 o'clock the same evening, and the following day at noon it was down to 10' 6" on gauge."

The number of hours therefore the Damoodah was above an inundating level was—

Between 27th and 28th 11 $\frac{7}{9}$ hours.

„ 28th „ 29th 24 „

„ 29th „ 30th 4 $\frac{1}{2}$ „

Total ... 40 hours, or 1 day and 16 hours.

44. The gauge readings and rain-fall in the basin are shewn in the following table :—

DATE.		Edilpore gauge reading.	Reading on the Raneegunge gauge.	Rain-fall in Calcutta.	Rain-fall at Burdwan.	Rain-fall at Bancoorah.	Rain-fall at Hazareebaugh.	REMARKS.
Month.	Day.							
July ..	25th	6' 0"	...	0.79	0.50	1.40		
Ditto ..	26th	6 2	...	4.04	0.80	0.00		
Ditto ..	27th	5 0	...		1.80	3.30		
Ditto ..	28th	14 6	18.0	0.21	0.00	0.00		
Ditto ..	29th	10 6	...	0.00	0.00	0.00		
Ditto ..	30th	8 0	...	0.00	0.00	0.20		
Ditto ..	31st	6 6	...	0.00	1.60	0.90		

Not known.

45. In 1860 the greatest flood took place on the 27th of July; the probable duration was—

Between the 25th and 26th $4\frac{4}{5}$ hours.

„	„	26th	„	27th	24	„
„	„	27th	„	28th	24	„
„	„	28th	„	29th	$7\frac{1}{5}$	„

Total ... 60 hours, or 2 days & 12 hours.

DATE.		Height on the Ranceegunge gauge.	Height on the Edilpore gauge.	Rain-fall at Cal- cutta.	Rain-fall at Burd- wan.	Rain-fall at Ban- coorah.	Rain-fall at Haza- reebaugh.	REMARKS.
Month.	Day.							
July ..	23rd	10' 0"	3' 2"	1.85	1.20	0.00	0.52	
Ditto ..	24th	9 0	5 9	0.12	0.00	2.50	1.18	
Ditto ..	25th	17 0	6 8	2.84	1.90	1.70	0.72	
Ditto ..	26th	18 0	10 10	2.02	0.80	1.80	0.54	
Ditto ..	27th	17 9	12 3	0.00	1.10	0.30	0.12	
Ditto ..	28th	12 6	10 9	1.10	0.20	0.40	1.00	
Ditto ..	29th	10 3	8 3	0.28	0.10	0.40	0.96	
Ditto ..	30th	8 6	6 9	0.49	0.00	0.30	0.60	

46. From this table some approximation to the actual overflow at Edilpore can be made.

The river commenced rising at Ranceegunge between the 24th and 25th, the rate being 4 per hour; it may have risen more rapidly, but the gauge readings are only taken once a day. On the 25th it stood at 17', and on the 26th had mounted to 18', from which it fell on the 27th to 12' 9" or 2.62" per hour. Assuming the duration of the

flood to have been about the same at Raneegunge and Edilpore, though it is more likely to have been prolonged at the latter place on account of the diminished depth of water and the lesser slope of the bed, I calculate the discharge to have been 57,302,587,906 cubic feet.

47. At Edilpore the quantity of water passing down the channel below the banks, when the gauge shews 10', is stated by Lieutenant Dundas to be 237,660 cubic feet per second, so that the present flood discharge amounted at the least to 51,334,560,000 cubic feet.

I conclude therefore that 6,000,000,000 cubic feet of water should have been subtracted to render the effects of the flood innocuous.

48. In 1861 and 1862 the only readings taken at Edilpore were after the river had already risen above inundation level, so that no calculations of the discharge can be given.

I subjoin the details I have been able to collect :—

YEAR.	DATE.		Height on the Edilpore gauge.	Height on the Raneegunge gauge.	Rain-fall at Calcutta.	Rain-fall at Burdwan.	Rain-fall at Bancoorah.	Rain-fall at Hazareebaugh.	REMARKS.
	Month.	Day.							
1861..	July ..	3rd	...	3' 6"	2.46	1.00	0.30	1.275	
" ..	" ..	4th	11' 3"	13 6	0.12	8.10	4.20	1.575	
" ..	" ..	5th	14 0	15 9	0.39	0.10	0.90	4.875	
" ..	" ..	6th	11 0	11 1	0.00	0.70	0.60	0.275	
1862..	June ..	17th	...	3 3	0.64	1.60	1.00	0.575	
" ..	" ..	18th	...	4 11	0.27	2.20	2.40	4.775	
" ..	" ..	19th	12 0	14 6	4.86	0.30	0.00	3.075	
" ..	" ..	20th	13 6	12 6	0.00	0.10	0.00	0.000	
" ..	" ..	21st	7 9	10 6	0.00	0.00	0.00	0.000	
" ..	" ..	22nd	...	8 3	0.00	0.20	0.20	0.000	

49. In 1863 the water commenced rising on the morning of the 25th of September.

At 10 A. M. it stood at 13' 3" on the Edilpore gauge.

„ 10 „	on the 26th	14' 10"	„	„	„
„ 10 P. M.	„ „	13' 8"	„	„	„
„ 7 A. M.	„ 27th	12' 4"	„	„	„
„ 12 „	„ „	10' 0"	„	„	„
„ 6 P. M.	„ „	8' 9"	„	„	„

This gives a duration on the 25th of 14 + 6 hours = 20 hours.

26th	24 „
27th	12 „

Total ... 56 „

Or 2 days and 8 hours.

50. The discharge at Edilpore below 10 feet would exceed 47,912,256,000 cubic feet, and that at Rancegunge at the very highest estimate not more than 63,800,000,000 from 12 o'clock on the 24th to the same hour on the 27th; so that if 16,000,000,000 cubic feet were stored up no dangerous flood would have occurred. This differs from Lieutenant Garnault's estimate, which was 73,713,551,040 cubic feet in the Upper Damoodah alone, but the readings on the gauge show that no flood remains at the same level for three days. I have entered those below:—

YEAR.	DATE.		Height on the Edilpore gauge.	Height on the Rancegunge gauge.	Rain-fall at Calcutta.	Rain-fall at Burdwan.	Rain-fall at Bancoorah.	Rain-fall at Hazareebaugh.	REMARKS.
	Month.	Day.							
1863	Sept. ...	23rd	Ft. Ins.	7' 9"	0.00	0.00	1.40	1.25	
„	„ ...	24th	...	11 7	0.40	0.30	2.90	0.25	
„	„ ...	25th	13 3	16 4	0.44	0.75	0.00	13.00	
„	„ ...	26th	14 9	16 0	0.00	0.00	0.00	0.75	
„	„ ...	27th	10 0	13 2	0.61	0.00	0.00	0.62	

51. In 1864 the river commenced rising at 10 A. M. On the 11th September at 12 (?) it stood at 10 feet, in the evening at 13' 4". At 4 A. M. on the 12th at 13' 11" and remained at that height till 8 A. M; on the night of the 12th it had receded below the gauge; this gives a duration on the—

11th of 12 hours and
on the 12th ,, 18 ,,

—
Total ... 30 hours, or 1 day and 6 hours.

52. The discharge at Edilpore under the same condition as before would exceed 25,667,280,000 cubic feet; that at Ranee-gunge between the 10th and 12th amounted to 31,000,000,000, leaving a surplus of 5,300,000,000 cubic feet to be stored up.

53. In 1865 no details were procurable to enable me to complete the defective register of the Edilpore gauge readings.

54. The following table gives the rain-fall, &c., for the years 1864 and 1865 :—

YEAR.	DATE.		Height on the Edilpore gauge.	Height on the Ranee-gunge gauge.	Rain-fall at Calcutta.	Rain-fall at Burdwan.	Rain-fall at Bancoorah.	Rain-fall at Hazareebaugh.	REMARKS.
	Month.	Day.							
1864	September...	9th	Ft. Ins.						
	"	10th	....	7' 4"	1.79	0.00	0.60	0.50	
"	"	11th	....	9 0	0.91	0.50	4.50	12.00	
"	"	12th	10 0	17 6	0.25	0.20	0.70	1.00	
"	"	13th	13 11	12 8	0.00	0.20	0.00	0.12	
"	"	14th	....	10 9	0.00	0.00	0.00	.....
1865	"	12th	....	8 2	0.12	0.30	0.00	0.12	
"	"	13th	....	7 5	2.36	0.85	3.80	1.15	
"	"	14th	13 3	20 0	1.11	3.05	0.00	0.50	
"	"	15th	14 6	12 6	0.00	0.00	0.00	0.00	
"	"	16th	....	11 8	0.00	0.00	0.00	0.00	

55. In 1866 the flood commenced on the morning of the 1st of July at 10 A. M. On that date it stood at 11' 6"
 By evening 14 0
 On the morning of the 2nd July 14 0
 In the afternoon it fell to 13 6
 But rose by 1 o'clock on the 3rd to 15 0
 After which it fell rapidly, and by 10 A. M. stood at 11 0

Its probable duration was—

On the 1st 14 + 5 hours = 19 hours

„ 2nd 24 „

„ 3rd 10 + 2½ „ 12½ „

Total ... 55½ or 2 days and 7½ hours.

56. The discharge in the river below its banks at Edilpore was about 47,270,574,000 cubic feet; that at Ranecgunge between the 30th of June at 12 o'clock and the 3rd of July at the same hour 59,170,586,400 cubic feet, giving a difference of nearly 12,000,000,000 cubic feet which would have to be stored up.

YEAR.	DATE.		Height on Edilpore gauge.	Height on Ranecgunge gauge.	Rain-fall at Calcutta.	Rain-fall at Burdwan.	Rain-fall at Bancorah.	Rain-fall at Hazareebaugh.	REMARKS.
	Month.	Day.							
1866	June	...	30th	Ft. Ins.					
	July	...	1st	14 0	18 6	0.80	5.00	4.80	9.00
	"	...	2nd	15 0	19 6	4.20	5.00	2.20	0.50
	"	...	3rd	...	16 2	1.32	0.50	0.60	0.62
	"	...	4th	...	12 3	0.00	0.10	0.40	0.25
	"	..	5th	...	9 11	0.13	0.10	0.00	1.12

57. The maximum height of these 10 floods is shewn in the following table:—

YEAR.	Date.	Height at Edil- pore.	Height at Ra- neengunge.	Year.	Date.	Height at Edil- pore.	Height at Ra- neengunge.	REMARKS.
			Ft. Ins.					
1857...	Aug. 24th	13' 0"	.....	1862	June 20th	13' 6"	14' 6"	
1858...	" 18th	9 6	.....	1863	Sept. 26th	14 9	16 4	
1859...	July 28th	14 6	18 0	1864	" 12th	13 11	17 6	
1860...	" 27th	12 3	18 0	1865	" 15th	14 6	20 0	
1861...	" 5th	14 0	15 9	1866	July 2nd	15 0	19 6	

58. To compare these floods, I subjoin the daily discharge when they were at their highest, commencing from the year 1860:—

YEAR.	DATE.		Cubic feet of water discharged.	Total.	REMARKS.
	Month.	Day.			
1860	July	...	25th	13,090,464,000	
"	"	...	26th	24,261,379,200	
"	"	...	27th	25,263,316,800	
"	"	...	28th	17,893,774,800	80,508,934,800
1861	July	...	5th	16,709,760,000	
"	"	...	6th	14,009,040,000	30,718,800,000
1862	June	...	20th	14,182,992,000	
"	"	...	21st	10,053,072,000	24,236,064,000
1863	Sept.	...	25th	15,184,476,000	
"	"	...	26th	20,619,302,400	
"	"	...	27th	16,614,144,400	
"	"	...	28th	11,539,800,000	63,957,722,800
1864	Sept.	...	11th	13,641,048,000	
"	"	...	12th	17,785,951,200	
"	"	...	13th	10,457,172,000	41,884,171,200
1865	Sept.	...	14th	14,638,212,000	
"	"	...	15th	20,849,918,400	
"	"	...	16th	11,195,208,000	46,683,338,400
1866	July	...	1st	11,109,060,000	
"	"	...	2nd	25,597,296,000	
"	"	...	3rd	22,464,230,000	
"	"	...	4th	22,464,230,000	

59. On only the seven occasions below did the discharge in the river during the space of 24 hours exceed in amount the quantity which could have been carried down without dangerous results to the country, showing how a prolongation by artificial means of the duration of the floods over even a few hours would have been advantageous :—

YEAR.	DATE.		Discharge at Raneegunge in 24 hours.	Discharge at Edilpore below 10' on gauge.	Difference more.	Number of days the excess should be held up.	REMARKS.
	Month.	Day.					
1860	July	26th	24,261,379,200	20,533,824,000	3,727,555,200	} Three.	
"	"	27th	25,263,316,800	.....	4,729,492,800		
1863	Sept.	26th	20,619,302,400	.....	85,478,400	One.	
"	Oct.	2nd	22,810,154,000	.....	2,276,330,400	One.	
1865	Sept.	15th	20,849,918,400	.....	316,094,000	One.	
1866	July	2nd	25,597,296,000	.....	5,063,472,000	} Three.	
"	"	3rd	22,464,230,400	.....	1,930,406,000		

This table shows that if the excess water could have been retained for three days the river would have kept below the safe level of 10 feet on the Edilpore gauge.

60. The number of floods occurring in any month from 1857 to 1866 is as below :—

YEAR.	NUMBER OF FLOODS IN					Total for each year.	REMARKS.
	June.	July.	August.	September.	October.		
1857 ...	...	2	2	1	...	5	
1858 ...	...	...	...	...	...	...
1859 ...	...	1	2	...	1	4	
1860 ...	...	1	1	...	...	2	
1861 ...	1	2	...	4	4	11	
1862 ...	1	8	2	...	1	12	
1863 ...	...	2	1	2	1	6	
1864 ...	...	...	1	1	...	2	
1865 ...	...	1	1	1	...	3	
1866 ...	...	1	1	1	...	3	
Total...	2	18	11	10	7	48	

61. The shortest spaces of time which elapsed between two successive floods were in July 1862.

MONTH.	Date.	Height of Flood.	Time to next Flood.	REMARKS.
July	4th ..	11' 11"	2	
	7th ..	10 0	5	
	13th ..	11 5	1	
	15th & 16th	10 6	1	
	18th ..	10 9	3	
	22nd ..	10 10	1	
	24th ..	10 10	3	
	28th ..	11 0	0	

62. The rapidity with which the water drains off after an excessive of rain is shewn most clearly by the gauge readings at Raneegunge.

In 1860 the greatest rise in 24 hours was at the rate of 4" per hour.

1861	"	"	"	5	"	"
1862	"	"	"	4-8	"	"
1863	"	"	"	2-3	"	"
1864	"	"	"	4-25	"	"
1865	"	"	"	6-3	"	"
1866	"	"	"	6-15	"	"

63. It is important here to notice that though some of the floods between 1857 and 1866 have caused great damage, none can have approached that which occurred in 1823, the remembrance of which is most vivid in the minds of the villagers residing both on the banks of the Upper Damoodah and Burrakur. Lieutenant Garnault notices in his report that it must have stood at least 10 feet above any subsequent one. I levelled up to the place pointed out to me as the limit on the left bank of the Damoodah at Ramghur and found it 28·16 feet above the high water level of 1866. On the Burrakur, the marks of a former high flood in the shape of mounds of white sand thrown up on the top of the right bank beyond the village of Tiliya were most distinct; the top was 30·64 feet above the bed, whereas the presumed high water mark of 1866 was only 9·86 feet. In two other places old inhabitants shewed me where villages and cultivated ground had been inundated, compelling them in one case to abandon the site altogether.

Colonel Goodwyn in preparing a design of bridging the Burrakur where the trunk road crosses it near Taldangah, notes that the flood in 1823 rose 33 feet above datum level, which is 11 feet above any observed height since that date. The enormous discharge of 581,636 cubic feet per second stated by that officer to have been the maximum amount passing through his section vastly exceeds anything observed in later years. I can only estimate the greatest discharge per second as follows:—The sectional area at the place mentioned above on the Burrakur was 12,870·41 feet, hydraulic mean depth 23,307, slope of bed 4·13 feet, and consequently discharge 160,713 cubic feet per second. As the area drained was 328·56 square miles, the discharge per square mile would therefore be 489 cubic feet per second. Assuming this for the whole 7,000 square miles constituting the catchment basin of the Damoodah above Ranéegunge, the maximum discharge becomes 3,423,000 cubic feet per second.

Taking Colonel Goodwyn's section the run off per square mile = 215 cubic feet per second, or for the whole basin 1,605,000 cubic feet per second, shewing that the flood was chiefly caused by an excessive fall of rain in the Hazareebaugh plateau. About the duration, &c., nothing is known, but making every allowance for the ponding up of water which the recipient in full flood must cause in the channels of its affluents, it cannot be doubted that the maximum flood discharge of 600,000 cubic feet per second assumed by Colonel Dickens in his report of 1853 is not above the truth.

64. The effects of these floods on the lower country have been fully described by the different officers who from time to time have had charge of the Burdwan Division. From the later reports, it appears that large quantities of sand are deposited on what was previously fertile land, rendering it in some places entirely barren, and in others only partially productive; further, that villages are often destroyed, and the inhabitants of every part of the inundated districts exposed to much misery and discomfort. It is, however, at present doubtful whether the fertilizing effect of the water where its velocity is checked and its silt deposited does not counterbalance the destruction caused by it at other spots, but it is certain that the evils caused by this unregulated river must increase in an accelerated degree every year, for not only is the bed silting up, thus diminishing the available drainage channel, but owing to the whole of the inundation water being thrown into the right bank, that also is gradually rising, forming a natural embankment, and tending still further to reduce the capacity of the channel for passing off the floods. The probable result of continued deterioration will be the opening up of some new outlet, down which the river, having left its old bed, will try to vent its entire water in one volume.

65. To prevent some of these evils, embankments have been constructed and are still kept on the left bank, those on the right bank having been removed to the extent of 20 miles to give a free spill to the flood water. There can be little doubt that in such a torrential river as the Damoodah, embankments placed longitudinally aggravate very nearly all the evils attending floods; they increase the rapidity of the current by confining it within narrow limits, and thus force the deposits to be carried to a greater distance down the river; they heap up the

water between, and add immensely to the destructive effects, if any part gives way.

In fact, the object in view is to allow free expansion to the water to moderate its velocity, and to force it to deposit its rich silt on the defenceless plains, and not to raise it to a great height, thereby increasing the strength of its current and causing it to burst its artificial bank, the inevitable result being violent scour of the soil and a rush of water charged with sand rendering a great quantity of rich soil barren for years. This subject has, however, been fully discussed by Colonel Dickens in his report of 1853, and the system has been partially abandoned on the river in question.

66. The following table gives the heights on five of the principal gauges during the four highest recorded floods, and suggests the idea that water passing between embankments from some cause not as yet explained acts differently to what we might have expected : in fact, the true law of its motion is not understood :—

DATE OF THE FLOOD.			Raneegunge.	Edilpore.	Pullah.	Mohumpore.	Puspore.	Amptah.
Year.	Month.							
1859	..	July ..	18' 0"	14' 6"	18' 0"	20' 3"	16' 9"	15' 0"
1863	..	September ..	16 4	14 9	20 0	21 6	16 5	14 3
1865	..	„ ..	20 0	14 6	18 3	21 6	19 6	18 0
1866	..	July ..	19 6	15 0	20 6	21 0	16 6	14 0

67. In 1859 and 1865 it will be observed that the readings on the Edilpore gauge were identical, whereas at Puspore the river rose

in 1865 2' 9" higher than it did in the former year ; whether this was caused by a ponding up in the lower reaches or no, I cannot say ; I merely note the fact.

68. In 1859 and 1863 the Edilpore gauge reading showed a difference of only 3", whilst the excess was 2' at Pullah and 1' 3" at Mohimpore.

69. I am compelled to leave this branch of my investigation incomplete as the gauges have not been connected by levelling ; it may, however, be considered certain that, even supposing the heights of the embankments as well as the distance they should be retired to have been accurately determined, and that such care has been exercised in their construction, &c., that the highest known or calculated flood could pass down without doing injury in a few years, the sand and silt brought down in the rainy season would entirely alter the sections and necessitate new retirements or extensive additions to the height of the embankments.

70. The only effectual remedial measure seems to be the construction of reservoirs on the various affluents.

71. The objections usually urged against them are—

1st,—The expense of their construction and maintenance.

2nd,—The destruction of cultivation over such an extensive area as must be taken up for them.

3rd,—The interruption they cause to free communication.

4th,—The probability of their being soon filled with sediment and no longer serving their purpose.

5th,—The danger they would expose the country to by bursting their barriers.

6th,—The evil consequences they would occasion by prolonging the flow of the inundations.

The 2nd objection is of little force, as the country where the sites have been found is generally covered with jungle.

The 3rd objection will be slightly felt where there are no roads, and, as the country is hilly and the tracts run along the high ground, any inconvenience under this head will be confined to a very few sites.

The 4th objection is more serious, but the reservoirs will have to be emptied so quickly and so often that it is nearly certain the greater part of the sediment will be carried out and a very small proportion left undisturbed.

The water escaping by the bursting of the dams would doubtless destroy some crops in the neighbourhood ; but, as most of the reservoirs will be close to the main river, the damage will not be great.

The 6th objection is also serious, but I have shewn in paragraph 59 that, if a certain quantity of water can be held up for three days, the height of the flood will be reduced to a safe level ; the fear will then be that a fresh flood will find the reservoir full. In consequence of this, Lieutenant Garnault proposed that each should be capable of holding $\frac{3}{4}$ ths of the greatest monthly rain-fall ; taking $\frac{7}{16}$ ths as determined by myself, this would give $\frac{7}{16} 24 \cdot 30 = 17 \cdot 01''$ or more than 276 $\frac{1}{2}$ thousand millions of cubic feet of water for the whole basin, if reservoirs could be formed on every affluent.

This 276 $\frac{1}{2}$ thousand millions is very nearly the quantity which was shed off the catchment in July 1862, and a reference to paragraph 61 will shew that there were eight floods in that month, the intervals between being on 3 occasions only 1 day,

	1 occasion	2 days,
	2 occasions	3 days,
and on	1 occasion	5 days.

The height on the Edlipore gauge, however, never exceeded 11' 11", and only three of them reached 11-0 ; the intervals between these three were respectively 8 and 14 days, during which sufficient time would have

elapsed to have cleared out the reservoirs to such a depth as would have prevented any rise in the river above 11 feet.

72. I propose, however, in all subsequent calculations to assume that it is necessary to retain $\frac{7}{10}$ ths of the greatest observed monthly rain-fall, or 17·01" for the whole basin, increasing it in the case of affluents flowing from the Hazareebaugh plateau to $\frac{7}{10}$ of 31·13', or 21·791", and in those on the lower portion of the Burrakur to $\frac{7}{10}\left\{\frac{22\cdot10+31\cdot13}{2}\right\}$ or 18·627". In those having their origin in the hills on the right bank of the Damoodah, I assume $\frac{7}{10}\left\{\frac{31\cdot13+16\cdot90}{2}\right\}$ or 16·81" to be correct, and in the more southerly districts $\frac{7}{10}$ 22·10, or 15·47". I have in each case taken the maximum monthly rain-fall, though they do not occur at all the stations in the same year.

73. Reservoirs may be either permanent or temporary; they may either collect the water for future use or merely check its progress for a time; these latter can only be used in the upper reaches; the former in any portion of the basin, provided their capacity is so great as to suffice under all circumstances.

74. Temporary reservoirs should not be constructed on the Damoodah lower down than 100 miles above the confluence of the Burrakur, as the head waters alone can be temporarily held up with advantage; this I establish from the following considerations.

75. Supposing the rain to commence at Burdwan and continue falling till it reaches Hazareebaugh, the lower portion of the river will have time to pass off a part of its flood before the upper reaches are affected: here, therefore, temporary reservoirs at the head would give still further time for the process of clearing the channel. If the rain is general over the whole basin on the same day, the upper waters flowing off the steep hills near the source will overtake that draining from the undulating ground lower down; here any retardation near the sources will be most efficacious, and the same result would follow if the rain commencing at Hazareebaugh should accompany the flood; but in these

two last cases any keeping back of the water near the middle or lower reaches would only increase the duration, and, in all probability, the height of the waters.

76. The following table shows the date of the greatest rain-fall at different places in the basin, and the corresponding floods from 1860 to 1866 :—

YEAR.	DATE.		Date of heaviest rain at Hazareebagh.	Date of heaviest rain at Bancoorah.	Date of heaviest rain at Burdwan.	Date of heaviest rain at Calcutta.	REMARKS.
	Month.	Day.					
1860	July ...	27th	24th ...	24th to 26th.	25th ...	25th & 26th.	Rain accompanied the flood.
1861	"	5th	5th ...	4th ...	4th ...	3rd ...	Rain commenced from below.
1862	June...	20th	18th & 19th.	18th ...	18th ...	19th...	Rain general at the same time.
1863	Sept.	26th	25th ...	24th ...	25th ...	25th...	Rain fell in the middle part first.
1864	"	12th	10th ...	10th ...	10th ...	9th...	Rain general at the same time.
1865	"	15th	13th ...	13th ...	14th ...	13th...	Ditto ditto.
1866	July ...	2nd	1st... {	June 30th July 1st & 2nd.	1st & 2nd.	2nd...	Rain fell in the middle part first.

77. Temporary reservoirs are not required on the Burrakur, as the only place suitable is eminently adapted for a permanent one, and, if the latter description can be constructed of sufficient capacity and at a moderate expense, its advantages are so great in holding up supplies of water for irrigation, &c., as to supersede the use of the former.

78. The list of the affluents of the Damoodah and Burrakur is given below. The area they drain and the length of their course have been taken from the Revenue Survey Maps when procurable; these, however, have not all been published, the survey being under revision.

Affluents of the Upper Damoodah.

NAME OF AFFLUENT.	Bank on which situated.	Length from source to confluence of the Burrakur.	Length from source to confluence with the Damoodah.	Distance from confluence of Damoodah to junction of Burrakur.	Area drained in square miles.	REMARKS.
		Miles.	Miles.	Miles.		
Thiling ...	Right	172 $\frac{1}{4}$	5 $\frac{1}{2}$	166 $\frac{3}{4}$	13.06	No map of this river was obtainable.
Nuggur ...	Left	168	8	160	21.81	
Mahlan ...	Right	170 $\frac{1}{2}$	12 $\frac{1}{2}$	158	35.49	
Chutti ...	Right	164	12	152	39.30	
Upper Haharoo	Left	164 $\frac{1}{2}$	15 $\frac{1}{2}$	149	95.80	
Suphee ...	Right	...	...	141	.....
Gurhee ...	Left	163	26($\frac{3}{4}$)	137	185	
Haharoo ...	Left	148 $\frac{1}{2}$	22 $\frac{1}{2}$	126	250	
Sowabera ...	Left	121	7	114	25.80	
Nakaree ...	Right	127 $\frac{3}{4}$	16	111 $\frac{3}{4}$	.....
Bhera ...	Right	100	16	84	The Bakaroo falls into the Konaree.
Bakaroo ...	Left	119 $\frac{1}{2}$	49	70 $\frac{1}{2}$	225	
Konaree ...	Left	134	69	65	550	
Khango ...	Right	79 $\frac{1}{2}$	19	60 $\frac{1}{2}$	.....
Gurgee ...	Right	...	...	43 $\frac{1}{2}$	.....
Tumoonaea ...	Left	101 $\frac{1}{2}$	56 $\frac{1}{2}$	45	368.79	
Gurga ...	Right	65 $\frac{3}{4}$	21	44 $\frac{3}{4}$	.....
Khodo ...	Left	57 $\frac{1}{2}$	22	35 $\frac{1}{2}$	130.22	
Tjree ...	Right	52 $\frac{1}{2}$	30	52 $\frac{1}{2}$	.....
Gowaie ...	Right	51 $\frac{1}{2}$	30	21 $\frac{1}{2}$	.....

Affluents of the Burrakur.

NAME OF AFFLUENT.	Bank on which situated.	Length from source to con- fluence of the Damoodah.	Total length of affluent.	Length from confluence with the Burrakur to that with the Damoodah.	Area drained in square miles.	REMARKS.
		Miles.	Miles.	Miles.		
Koclo ...	Left ...	...	12	...	.....
Aktho ...	.....	...	...	115½	.....
Keso ...	Left ...	120	14	106	.....
Rickhurro ...	Left ...	115½	13	102½	.....
Bursote ...	Right ...	121	29	92	.....
Khero ...	Right ...	102	11	91	47.40	
Bureto ...	Left ...	101½	16	85½	50.37	
Hurdee ...	Right ...	89½	10	79½	48.88	
Argo ...	Left ...	93½	24	69½	.....
Tando ...	Left ...	...	...	69¼	24.00	
Churkee ...	Right ...	66	17	49	.....
Gondeizo ...	Right ...	55½	8½	47	.....
Oosree ...	Left ...	...	...	45	.....
Rajheca ...	Left ...	...	...	24	.....
Khloodga ...	Right ...	41¾	41	¾	207	

79. On eight of these affluents of the Damoodah and on five of those flowing into the Burrakur, sites more or less favorable for reservoirs have been discovered, as well as one on each of the main rivers; these I propose giving in their order.

80. The Damoodah has been fully described by Lieutenant Garnault, and little remains to be added.

About four miles below its source it is an insignificant stream, 50 feet wide: here being joined by the Sitahee River it increases to 83 feet, and probably discharges between 3 and 4,000 cubic feet during its highest floods.

Name of River.	Place where section was taken.	Sectional area square feet.	Hydraulic mean depth.	Fall of feet per mile.	Mean velocity feet per second.	Distance between limits of high water.	Wet perimeter.	Maximum discharge cubic feet per second.	Area drained square miles.	REMARKS.
Daneedah.	Below junction of the Sitahee	267.81	3.31	19.87	10.32	79	80.8	2766.3	...	
	8450' below ...	333.06	3.44	19.87	11.24	83	84.8	3744.9	...	

81. Nineteen miles further down it is joined on the right bank by the Mahlan or Upper Suphee River, on which a favorable site for a reservoir occurs.

82. This river being a type of the rivers rising on the hills to the south of the basin merits description.

After flowing for 5 miles along the plateau with a slope of more than 16 feet per mile it descends into the low land down a succession of steep rocky ledges, the fall being in excess of 90 feet in the mile. On reaching the low land, it continues its course over a series of rocky falls, but rapidly loses its torrential nature, and near its junction with the Damoodah runs in a deep and sandy bed; at its mouth it is evidently ponded back at certain times by the recipient.

A site for a dam appeared where the Gunyaree and Neemantollah Hills, on which are situated villages of the same name, approach one another.

The area drained above this point is 32.3 square miles, the water therefore to be retained = $32.3 \times \frac{7}{10} \times \frac{1}{2} \times (31.13 \times 16.90) \times 2,323,200$ or 1,261,449,161 cubic feet. The channel of the river itself, supposing the water to be ponded up for a distance of $2\frac{1}{2}$ miles, would give the necessary space for storing 53,600,000 cubic feet, but the slope

of the valley is so great, being at the rate of 17.98 feet per mile, as to make it doubtful if more than 500,000,000 cubic feet could be retained with advantage; the dam would require to be 45 feet in height.

The village of Burbee will be destroyed, but nearly the whole of the basin is covered with jungle and consequently the damage done will be very slight.

Place where section was taken.	Sectional area square feet.	Hydraulic mean depth.	Fall of bed feet per mile.	Mean velocity feet per second.	Distance between limits of high water.	Wet perimeter.	Maximum discharge cubic feet per second.	Maximum discharge calculated from $825 \sqrt[4]{m^3}$.	Area drained square miles.	Cubic feet run off per second per square mile.
Site of proposed dam	1174.97	4.55	17.98	11.40	257	258.2	13.394	11.177	32.30	414

83. Below the confluence of the Mahlan River the hills which flank the Damoodah in this portion of its course approach within a distance of 3 or 4,000 feet. The best spot for a reservoir will be in this locality, as the Girwa Hill on the right bank and the Baudha Toorgree on the left throw off subsidiary spurs, which narrow the gorge considerably. The area drained up to this point being nearly 225 square miles, the water to be retained will equal $225 \times 16.81 \times 2,323,200$ or 8,786,923,200 cubic feet, or deducting that already provided for, supposing the Mahlan dam to be built, a little more than eight thousand millions; the slope of the bed being 9.30 per mile, a 100 feet dam would keep back the water to a distance of $10\frac{7}{10}$ miles. Assuming 10 miles to allow for any increase in the rise, the channel itself would have a capacity for holding 660,000,000 cubic feet: the River Mahlan and its valley, as well as the Nuggur Nuddee, would also be available for about $2\frac{1}{2}$ miles up each. I think that the area will be sufficiently large to contain the entire 8,000,000,000 cubic feet.

Place where section was taken.	Sectional area square feet.	Hydraulic mean depth.	Fall of bed feet per mile.	Mean velocity feet per second.	Distance between limits of high water.	Mean perimeter.	Maximum discharge cubic feet per second.	Maximum discharge calculated from $825 \sqrt{m^3}$.	Area drained square miles.	Cubic feet run off per square mile per second.
Site of proposed dam	4935.91	15.127	9.30	15.03	321	326.3	74.193	47.928	224.72	330
6725' below	3519.24	14.23	9.30	14.64	229½	247.3	51.529	..	..	229

The latter section probably gives the correct discharge.

84. The Chutter Nuddce is a small river flowing over a rocky bottom : neither on it nor on the Upper Haharoo were there sites at any place where the waters could be usefully controlled.

85. The Suphee River is one of the principal affluents on the right bank. On it I found two sites, one between the village of Tikataree and a spur from the Dhoondhee Toongree, and the other 1 mile 4,800 feet lower down between the Bellangee Hill and the Dhoondhee Toongree, a little to the north of the village of Rai ; the latter would command a greater drainage area and be in other respects more suitable. The mean height of the dam might be considerably reduced by a slight diversion of the line on the right bank, but a natural foundation of strong conglomerate rock rising on the lower side, about $3\frac{1}{2}$ out of the water and running across the river, determined my choice. It may however be found that this will not form a suitable base, in which case the alteration in the direction proposed will bring the right extremity at once on the high ground. The valley of the Suphee above this widens out in two or three places, but from the proximity of high hills it cannot be calculated on to hold any great quantity of water, unless an expensive dam is constructed ; one of 100 feet in height would probably pond up the water more than 8 miles, as the slope of the bed between the sites was 7.124 feet per mile, and thus will allow

an ample margin for the increased slope in the upper portions; the river itself would afford storage room for 564,000,000 cubic feet.

86. The map of this river and its basin could not be supplied me, as the survey was under revision. Supposing, therefore, that the catchment basin extends over 40 square miles, the water to be retained will equal $40 \times 16.81 \times 2,323,200 = 1,562,119,680$ cubic feet, and this will be easily contained by a lower dam than that proposed.

Place where section was taken.	Sectional area square feet.	Hydraulic mean depth.	Fall of bed feet per mile.	Mean velocity feet per second.	Distance between limits of high water.	Wet perimeter.	Maximum discharge cubic feet per second.	Maximum discharge calculated from $S25 \frac{1}{4} \sqrt{m^3}$.	Area drained square miles.	Cubic feet run off per square mile per second.
10,000' above site of proposed dam ...	3613.15	12.09	71.24	11.81	267	278.10	42.678	Not known	Not known	...

87. The Gurhee is the next large affluent and falls into the Damoodah on the left bank about 4 miles lower down. The site for the dam was fixed upon by Lieutenant Garnault at a spot 6 miles below Tendwa and about 8 above the junction with the main river, where the Juree and Chiloomaree Hills approach one another. To show the necessity for a high dam, I have made the following calculations. As the slope of the channel is about 8.64 feet, a 55 feet dam will pond the water up the stream to a distance of more than 6 miles across section taken $4\frac{1}{4}$ miles above the proposed site; assuming this height gives an area of 13706.79, which would be filled up with water, the breadth being 1719 feet, the mean depth will be nearly 8 feet, supposing the breadth to remain nearly the same at each mile lower down and the depth to increase 8.64.

The sectional area of the 1st mile below will = 28,604 suppl. feet.

"	"	2nd	"	"	= 43,456.	"
"	"	3rd	"	"	= 58,308	"
"	"	4th	"	"	= 73,160	"

The capacity of the 1st mile below will = 111,698,400 cubic feet.

"	"	2nd	"	"	= 190,238,400	"
"	"	3rd	"	"	= 268,656,960	"
"	"	4th	"	"	= 347,075,520	"
Total					917,669,280	

If, however, the height is increased to 80 feet, the cross section becomes equal to 81,075.73 superficial feet, the breadth is 4289 and mean depth 18.67.

The sections across are increased to 117.133
154.189
190.817
227.874

with a capacity of 523,269,120
715,290,080
937,215,840
1,105,351,600

Total ... 3,282,126,640 cubic feet.

The amount of water to be stored is under $21,791 \times 185 \times 2,323,200$, or 9,365,597,472 cubic feet, and as this will be set back 9 miles at least 7,000,000,000 will be provided for. The damage to property would be very small, as the valleys are covered with jungle, and at Tendwa the water would not rise more than 28 feet above the bed, which would not injure that village.

Place where section was taken.	Sectional area square feet.	Hydraulic mean depth.		Fall of bed feet per mile.	Mean velocity feet per second.	Distance between limits of high water.	Wet perimeter.	Maximum discharge cubic feet per second.	Area drained square miles.	Cubic feet run off per square mile per second.	Maximum discharge calculated by the formula $825 \sqrt[4]{m^3}$.
Site of proposed dam..	2600.0	6.99	8.64	9.89	370.3	371.6	25.729	...	...	...	...
	3089.63	5.69	8.64	8.92	...	542.98	27.573	185	149	41.384	

88. The Haharoo falls into the Damoodah on the same bank as the Gurhee, but 11 miles lower down; the site fixed upon by Lieutenant Garnault is in a narrow gorge formed by the approach of the Acharoo and Angoo Hills close to the village of Angoo. The distance levelled across was 1753 feet from a height above the bed on the right bank of 7874 feet, and on the left of 118·33, but the hills rise to such a height on the right, that, with a short embankment, there will be little difficulty in constructing a dam 110 feet in height, and, as the slope of the bed is 9·54 feet per mile, the setting back of the water will extend to a distance of more than 11 miles.

The amount of water to be retained $= 21·791 \times 250 \times 2,323,200 = 12,656,212,800$ cubic feet across section taken about $4\frac{1}{2}$ miles above the site, gives an area of 27,420 superficial feet in a distance of 2,451 feet; the mean depth is consequently only 11 feet. Some of the valleys of the smaller tributaries are, however, very deep; that of the Singrahee Nuddce being particularly so; the soil from the margin of its drainage area being cut by the action of the water perpendicularly downwards, I think there will be sufficient capacity to store up about 8,000,000,000 cubic feet.

Place where section was taken.	Sectional area square feet.	Hydraulic mean depth.	Fall of bed feet per mile.	Mean velocity feet per second.	Distance between limits of high water.	Wet perimeter.	Maximum discharge cubic feet per second.	Maximum discharge calculated from the formula $S^2 \cdot \sqrt{m^3}$.	Area drained square miles.	Cubic feet run off per square mile per second.
Site of proposed dam	3634·91	11·85	9·54	13·76	301	306·74	49·191	51·869	250	197

89. At the junction of the Haharoo with the Damoodah the slope of the bed of the former increases to 13·3 feet per mile, owing, doubtless, to the water being kept back and then suddenly vented on the fall of the latter.

90. The Damoodah itself after receiving this important tributary widens considerably, but the bed continues sandy, the slope being only

4.85 feet per mile. I give below the discharge, &c., of the Damoodah at this point as well as at Ramghur:—

Place where section was taken.	Sectional area square feet.	Hydraulic mean depth.	Fall of bed feet per mile.	Mean velocity feet per second.	Distance between limits of high water.	Wet perimeter.	Maximum discharge cubic feet per second.	Maximum discharge calculated from the formula $825 \frac{4}{3} \sqrt{m^3}$.	Area drained square miles.	Cubic feet run off per square mile per second.
Below the confluence of the Maharo...	916.866	13.49	4.73	10.16	673	679.1	93.181	...	...	...
At Ramghur...	997.09	16.35	6.50	13.12	607	610.5	1,30,913	146,708	1,000	147

91. On the Nakaree, Bhera, and Kharyo Rivers I found no suitable sites.

92. The next large river on the left bank is the Konaree. The following table gives the sections I took both on it and its large tributary, the Bakaroo:—

Place where section was taken.	Sectional area square feet.	Hydraulic mean depth.	Fall of bed feet per mile.	Mean velocity feet per second.	Distance between limits of high water.	Wet perimeter.	Maximum discharge cubic feet per second.	Maximum discharge calculated from the formula $825 \frac{4}{3} \sqrt{m^3}$.	Area drained square miles.	Cubic feet run off per square mile per second.
BAKAROO.										
26,061 above site of dam...	8061.39	15.43	10.25	17.78	1862	199.6	49,336	...	...	...
24,745 above site of dam...	3689.28	9.14	10.25	12.32	400	403.4	45,402	...	...	...
21,521 above site of dam...	5160.24	15.74	9.96	15.35	329	336.6	81,374	...	...	...
At site of proposed dam...	4822.34	13.17	11.49	15.65	361	366.0	75,481	47,928	225	335
KONAREE.										
11,623' above upper dam...	3368.49	11.44	20.42	10.45	291.2	294.3	65,546	...	...	...
Site of upper dam...	3431.72	11.24	23.73	22.26	302.7	305.3	76,205	60,900	309.06	246
22,177 above middle dam...	4083.3	11.76	15.45	15.32	343	347.1	62,567	...	...	...
Site of middle dam...	3870.41	10.33	12.32	16.06	372	374.58	62,170	73,640	398.95	155
Site of proposed lower dam	6978.62	11.18	9.67	13.23	538.4	623.87	92,391	68,781	49,655	186

There are several discrepancies, but the bed was in some places so full of rocks as to render the calculations difficult.

93. The Bakaroo has been fully described by Lieutenant Granault, who fixed on a site for a dam about 2 miles east of Lalghur, where the Lugie and Telingo Hills approach within a distance of about 1,800 feet.

The valley between these hills for some distance is contracted, and though it widens out near the village of Leirgo it narrows again at Ghosee.

The water to be retained is $21,791 \times 224 \times 2,323,200$, or 11,390,501,520 cubic feet; to do so the dam must be of enormous dimensions. The rise in the slope of the river above the proposed site is in the 1st mile 13.02 feet.

2nd „ 9.92 „

3rd „ 10.13 „

4th „ 10.08 „

5th „ 10.42 „ or a mean of 10.73 feet.

So that a 130 feet dam will pond the water up 12 miles.

A section across the Bakaroo, 5 miles above the site fixed on, gives an area of 82,929 superficial feet, and as the breadth = 26.02 feet, the mean height will equal 31.8.

If we suppose the valley to continue of the same dimensions with only the difference resulting from a fall of 10.73 feet, the sectional area of the next mile below will = 110,663.06 superficial feet, and will possess a storage capacity of 511,056,480 cubic feet. As this may be considered a maximum quantity to be held up in any one mile, there is no doubt that more than $5\frac{1}{2}$ thousand millions of cubic feet cannot be accommodated in the valley of the main river even with a dam so lofty as 130 feet. Some relief will be experienced in the valley of the Chutwa Nuddee, a considerable stream, which joins the Bakaroo on its left bank $3\frac{1}{10}$ miles above the proposed site; it will probably be ponded up 4 or 5 miles.

94. The Konaree River is far the largest affluent of the Damoodah : it rises 73 miles to the east of Hazarcebaugh and only 3 miles to the north of the source of its tributary, the Bakaroo; it has a total length of 69 miles.

The site for a dam on this river was fixed on by Lieutenant Garnault at a spot where a spur from the Puriary Hill, on which the villages of Soang and Goomea Chuttia are situated, rises as it approaches the channel and is known as the Goolu Luckoo Hills.

On the left bank a spur from the Tutwa faces it.

The ground in rear of the Goolu Luckoo Hill dips, so that a higher dam than 105 feet would probably entail heavy embanking. The bed of the Konaree at this spot is entirely of sand, but at a distance of $1\frac{1}{2}$ miles above rocks begin to appear, and in another half mile the whole surface is covered with them.

The slope of the 1st mile is 9.02 feet.

„	„	2nd	„	10.17	„
„	„	3rd	„	22.85	„
„	„	4th	„	43.30	„
„	„	5th	„	25.97	„

or 22.14 feet per mile. A 105 feet dam will therefore only set back the water $4\frac{7}{10}$ this miles. The catchment basin being 496.55 square miles is capable of throwing off in a month of excessive rain $496.55 \times 21.791 \times 2,323,200$, or 25,137,769,853 cubic feet; it will, I think, be a high estimate if this reservoir is considered capable of holding 4,500,000,000 cubic feet.

95. A few miles higher up the river I found a site where an offshoot from the Tellingha Hills on which the Bulwada Telegraph Tower is situated touches the river to the north of the village of Domo. This spur is known as the Bukh Bhookiagra Hill and faces the Tiliya Tongree. As, however, the latter only rises 79.55 feet above the bed of the river, the height of the dam must be limited to that. The river ran along a rocky bottom nearly as far as I levelled, the only exception being in the first $\frac{3}{4}$ of a mile.

The slope of the 1st mile = 10.51

„	„	2nd	„	= 21.39
„	„	3rd	„	= 15.50
„	„	4th	„	= 9.14

Mean ... 14.13 per mile.

A dam of 79 feet will therefore hold up the water to the distance of $5\frac{1}{2}$ miles. I estimate the storage capacity at 4,000,000,000 cubic feet.

96. A site for a third reservoir was found where the Konaree runs between high hills to the north of Horlung. The height of the Beiran Hill, which rose on the right bank, was 137·87 feet above the bed, and that of the Campe Deerce Hill on the left bank 101·43, so that the dam will be limited to 100 feet in height. The bed was everywhere covered with rocks.

The slope in the 1st mile is 23·58 feet.

„	„	2nd	„	30·59	„
„	„	3rd	„	15·88	„
„	„	4th	„	24·97	„

Mean	...	23·75	„
------	-----	-------	---

The river will therefore be ponded back for $4\frac{1}{5}$ miles. If it was possible to retain $\frac{7}{10}$ ths of the maximum monthly rain-fall, this upper reservoir should be made capable of holding $309\frac{1}{2} \times 21\cdot791 \times 2,323,200 = 15,668,391,446$ cubic feet, as $309\frac{1}{2}$ miles drain into the river above, and the lower ones will not suffice to contain their own portion of the basin drainage. Considering, however, the great slope of the valley and the limited height of the dam, 3,000,000,000 will probably be an outside estimate for the capacity. The tributaries which join the Konaree will give some relief, but their slopes exceed those of the recipient.

These are the Bairam, 1256 feet above the site of the dam of the right bank,

Hatto, 1556	„	„	„
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and the Siwanmy, 2 miles 2300 feet on the left bank.

The latter is as large as the Konaree itself above the confluence, and passes down such a volume of water as to necessitate at a point

18 miles higher up the construction of a bridge, giving 195 running feet of waterway.

97. The water to be retained in the three reservoirs is as follows:—

Between lower and middle dam	..	4,500,000,000	cubic feet.
„ middle and upper „	..	4,000,000,000	„
Above upper dam	..	3,000,000,000	„
		<hr/>	
Total	..	11,000,000,000	„
		<hr/>	

98. The breadth of the channel of the river at the site of the 1st dam was 588 feet; of the 2nd dam, 372 feet; of the 3rd dam, 302 feet.

So that its capacity as a reservoir will not exceed	..	745,000,000
		495,000,000
		334,800,000
		<hr/>
Total	..	1,574,800,000

The river everywhere was thoroughly torrential in its nature and the bed covered with rocks.

99. The Junoonca River is the next on which sites for reservoirs have been discovered. It rises to the east of the Hazareebaugh plateau, flows in an easterly direction for about 25 miles, and then turning south falls into the Damoodah after a total course of 56½ miles. It drains nearly 369 square miles.

100. The first site is situated a short distance above the confluence with the Damoodah, where a low range of hills, a continuation of the spur on which the village of Doomra stands, approaches the river, and

is faced on the right bank by the Gutwar spur.* This latter appears to be an offshoot from the Dogdahar Hill, and takes its name from the village of Gutwar. The site is an inferior one, the distance to be embanked being nearly $1\frac{2}{5}$ ths miles long, the slope of the bed is also excessive, as the following levels show :—

For the 1st mile	..	..	..	12·60 feet.
„ 2nd „	..	..	..	7·09 „
„ 3rd „	..	..	..	11·30 „
„ 4th „	..	..	..	19·26 „
				<hr/>
Mean	..	..	..	12·56 feet.
				<hr/>

Nearly along the entire length rocks and rocky ledges shewed the torrential nature of this important tributary of the Damoodah.

The dam must be constructed about 100 feet high, as one more lofty would entail a greatly increased length of embankment, and one lower would not enable us to hold up the necessary quantity of water.

With such a dam, the river would be ponded up 8 miles. The drainage area between the 1st and 2nd sites was 156·69 square miles, the water to be retained will be $156·69 \times 15·47 \times 2,323,200 = 5,631,423,557$ cubic feet. The river itself will be capable of storing up 760,320,000 cubic feet, and though the tributaries are numerous and their channels deep, I do not think the valley will hold more than 5,000,000,000 cubic feet.

101. The 2nd site is a little to the west of Doomree on the Trunk Road, where a spur from Parisnath approaches the river on left bank. The particular hill on this spur which touches the left bank is known as the Goodaree. On the right bank the ground rises gradually to the Burwa Tongue on which the village of Jamagoorea is situated. The drainage area above amounts to 192·95 square miles, and the water to be held up to $192·95 \times 21·791 \times 2,323,200 = 9,768,057,024$ cubic

feet ; and, as the slope of the bed is 10·007 feet per mile, a 100 feet dam will, whilst setting back the water about 10 miles, retain above 6,000,000,000 cubic feet.

The proximity of the Trunk Road may necessitate the construction of a lower dam than the one proposed, as the Colgo, which falls into the Jumoonea about 600 feet above the proposed site, is crossed $2\frac{1}{2}$ miles higher up on its course by a bridge of 5·33 feet arches, and in all probability must be covered with water if the scheme here mentioned is carried out. I examined the Jumoonea up to where it diminished to a small stream 50 feet wide, but found no other spot in any way suitable.

Place where section was taken.	Sectional area square feet.	Hydraulic mean depth.	Fall of bed feet per mile.	Mean velocity feet per second.	Distance between limits of high water.	Wet perimeter.	Maximum discharge cubic feet per second.	Maximum discharge calculated from the formula $825 \sqrt[4]{m^3}$.	Area drained square miles.	Cubic feet run off per square mile per second.
6,669 feet above upper dam ...	2629·97	8·93	10·007	12·03	292	294·34	31,641	...	...	...
Site of upper dam ...	4577·60	7·14	10·007	10·76	636·5	640·86	49,256	...	192·95	255
4 miles above lower dam	3742·39	10·09	12·48	14·28	368	370·6	53,451	...	...	...
Site of lower dam ...	4035·6	15·64	12·48	14·67	369·8	379·03	59,209	66·706	349·64	169

102. The Gurga and Tjree rivers presented no favorable sites.

103. On the Gowaie about $30\frac{1}{2}$ miles above its junction with the spur Oamoodah near the village of Podoodah occurs a gorge 46 feet deep.

As the slope of the bed is 16.18 per mile, the water will be kept back $2\frac{1}{5}$ th miles. I estimate the capacity from a cross section taken about $1\frac{1}{2}$ miles above the site to be about 500,000,000 cubic feet. The map of the country near the sources of the river not having been supplied me, I am unable to give the drainage area.

Place where section was taken.	Sectional area square feet.	Hydraulic mean depth.	Fall of bed feet per mile.	Mean velocity feet per second.	Distance between limits of high water.	Wet perimeter.	Maximum discharge cubic feet per second.	Maximum discharge calculated from the formula $825 \sqrt[4]{m^3}$.	Area drained in square miles.	Cubic feet run off per second per square mile.
GURGA.										
About $3\frac{1}{2}$ miles above junction ...	1928.08	9.27	10.88	12.78	203	208	24,645	...	...	...
1 mile lower down ...	1703.12	8.45	10.88	12.205	192.5	201.5	207,787	...	...	...
$\frac{1}{2}$ mile lower...	2576.74	10.64	10.88	13.69	233.5	242	35,298	...	...	...
$1\frac{1}{4}$ mile lower	2131.31	11.05	16.43	17.15	212.3	220	41,698	...	...	...
TJREE.										
$3\frac{1}{5}$ miles above junction with the Gowaie	2116.20	11.52	8.11	12.30	175	183.6	26,041	...	...	...
1 mile lower down ...	2427.43	10.508	8.11	11.75	225	231	28,521	...	...	...
$2\frac{1}{5}$ miles lower	3381.58	1.43	13.10	16.24	265	272	54,927	...	...	...
GOWAIE.										
Sectional dam	747.02	5.13	16.18	11.60	144	145 $\frac{1}{2}$	86,655	...	...	...
About 4 miles above junction with Damoodah ...	5625.31	11.19	4.56	9.09	497	502.3	51,165	...	...	...
$3\frac{1}{2}$ miles lower	9531.55	9.716	5.81	9.56	976.5	981	91,149	...	...	...

104. • The results of this investigation on the Upper Damoodah is shown in the following table :—

Name of Basin.	Maximum height of dam.	Cubic feet of water to be retained.	Area drained above site of dam square miles.	Mean height of dam.	Total length of dam in feet.	Number of miles the main river will be ponded up.	Slope of the bed of the river feet per minute.	REMARKS.
Mahcan ...	45	500,000,000	32.30	10.74	2,214	2 $\frac{1}{2}$	17.98	
Damoodah	100	8,000,000,000	192.42	46.11	3,952	10 $\frac{7}{10}$	9.30	
Gurhee ...	80	7,000,000,000	185.00	24.47	10,952	9	8.64	
Suphee ...	1008	1,562,119,680	40.00	...	...	8	7.124	
Hokaroo...	110	8,000,000,000	250.00	68.19	1,856	11	9.51	A good site.
Bakaroo ...	130	7,500,000,000	225.00	60.04	1,726	12	10.73	Ditto ditto.
Konaree...	105	4,500,000,000	496.55	49.86	3,041	4 $\frac{7}{10}$	22.14	
Ditto ...	79	4,000,000,000	398.95	30.37	2,231	5 $\frac{1}{2}$	14.13	
Ditto ...	100	3,000,000,000	309.66	45.60	1,089	4 $\frac{1}{6}$	23.75	Ditto ditto.
Jumoonia	100	5,000,000,000	349.64	33.33	7,132	8	12.56	
Ditto ...	100	6,000,000,000	192.95	54.42	7,553	10	10.007	
Gowaie ...	46	500,000,000	Unknown.	...	...	2 $\frac{4}{5}$	16.18	

Total 55,062,119,680 cubic feet of water in 12 reservoirs.

The area in rear of the dams being more than 1,770 square miles, or about $\frac{2}{3}$ th of the basin of the Upper Damoodah.

105. The Burrakur being the affluent of the Damoodah, which almost equals the Upper Damoodah in size, requires to be fully described. It rises about 7 miles to the north of Hazareebaugh and descends in the first 13 miles of its course from a height of 2,000 feet to 1,200 above the level of the sea. On reaching this lower level it flows along a sandy bed of considerable width and of slight declivity. Its direction is

northerly, till it crosses the Trunk Road above Burhee, when it turns eastward and continues so for 120 miles; it then inclines to the south and falls into the Damoodah a little more than 3 miles below the Trunk Road at Taldanga, which it again crosses. Its total length is 171 miles, and its catchment basin about 2,700 square miles. The increase in its size and discharge is so great as to necessitate a bridge being built over it with a waterway of 1,885 running feet near its confluence, whereas 142 miles above one with 450 running feet sufficed. The total fall of this river between Burhee and the junction with the Damoodah = 6.03 feet per mile, but this is not uniformly distributed, in the upper portion it being far less, and in the lower part greater, as the following levels show.

The measurements are given from the source downwards.

	<i>Mile. Foot.</i>			<i>Mile. Foot.</i>		
from the	26	2558	to the	39	430	4.17 is the slope per mile.
„	39	430	„	42	2722	4.13 „ „
„	42	2722	„	49	1416	3.72 „ „
„	49	1416	„	53	4546	3.52 „ „
„	53	4546	„	61	2409	3.53 „ „
„	61	2409	„	72	1076	4.027 „ „
„	72	1076	„	82	4645	6.22 „ „
„	82	4645	„	96	4015	5.02 „ „
„	96	4015	„	110	2461	6.608 „ „
„	110	2461	„	130	1867	7.490 „ „
„	130	1867	„	142	5078	8.09 „ „
„	142	5078	„	149	646	9.89 „ „
„	148	646	„	162	5109	8.61 „ „
„	162	5109	„	171	4205	4.28 „ „

106. These levels will shew at glance what a dangerous river the Burrakur is as regards the rapid transmission of its water into the Damoodah, the slope within 9 miles of that river being 8.61 feet per mile.

107. The bed of the upper portion is entirely sandy, but on approaching the lateral offshoots from Parisnath it changes and becomes exceedingly rocky; this continues up to the 163rd mile, when sand again appears and rocks disappear.

108. The Damoodah presents a marked contrast, for whereas it falls 226·5 feet in the last 50 miles of its course above the confluence, or 4·53 feet per mile, the Burrakur in the same distance has an inclination of 7·5. It is therefore to be regretted that the latter river traverses a district where there are so few suitable sites for reservoirs.

109. From Tiliya, a few miles below Burhee, this river drains a well cultivated district almost completely bare of hills of any kind till it arrives within the influence of Parisnath. Here, as well as below, where continuous spurs again disappear and only detached hills present themselves, the country is covered with jungle, and it is in this portion of the catchment basin that the reservoirs must be formed.

110. The most important tributaries are, on the left bank, the Argo and Oosree, and on the right the Bursote and Khoodya. The next in size are the Keso on the left and the Khero Khoodya on the right bank.

111. I have found sites for reservoirs on the Burrakur itself and on the Khoodya and Churkee, as well as on three minor affluents, *viz.*, the Tando, Gordengo, and Rajheea.

112. From observations taken in the Burrakur, I have calculated the discharge per second during the highest floods in 1863 to be 147,577 cubic feet, or 59 cubic feet per square mile per second.

In 1865 to be 176,940 cubic feet or 70 cubic feet per square mile per second.

„ 1866 „ 132,540 „ 53 „ „ „

113. Lieutenant Garnault in his report states that the discharge to the Damoodah in 1863 was 284,388·7 cubic feet per second when the river was at its highest, *viz.*, 67·7 cubic feet per second were shed off from each square mile per second.

114. Assuming 70 as the maximum co-efficient applicable to both rivers, the joint discharge should be not less than 480,000 cubic feet. I do not, however, believe that this quantity of water is ever passed down the channel in a second, as the highest floods are not simultaneous, and if by chance they should be, one is certain to find the other back; the flood of 1823 is always left out of account.

115. The first site for a reservoir is on the Burrakur itself near the village of Tiliya, where two ranges of low hills which hem in the river for about $7\frac{1}{2}$ miles approach within 1,600 feet of one another. The slope of the bed being only 4.13 feet, and the heights of the hills more than 130 feet; a dam of at least 130 feet could be adopted, which would set back the water about $31\frac{1}{2}$ miles, but the proximity of the Upper Burrakur Bridge limits the size to 54 feet; this will pond up the water about 13 miles.

The drainage area being 270 square miles, the water to be retained will be $270 \times 2,323,200 \times 21.79 = 13,668,083,560$ cubic feet. I have the detailed levels of this basin and propose submitting them in a subsequent report, but as they are not worked out, I only calculate roughly that the capacity of the reservoir will be $3\frac{1}{2}$ thousand millions of cubic feet. The ground is more cultivated in this portion of the basin than in most other places, and opium is grown in considerable quantities, but the villagers appear to be in no want of water for irrigating purposes, their numerous shallow wells supplying all their wants.

116. From Tiliya to the Tando River, a distance of 63 miles, though the rivers Bursote and Khoro on the right, and the Eerga (Argo) Keso and Ruckhurro on the left fall into the Burrakur, no suitable site was discovered.

117. The Bursote is probably the largest tributary: a cross section taken on it between the villages of Ghorbunda and Ghoormoon-doo gave a height of $58\frac{1}{2}$ feet above the bed, for the summit of the hills forming the gorge; the breadth across was 2,000 feet and the slope of the bed 7.66 feet, so that the water could be stored to a distance of $7\frac{1}{2}$ miles up the valley; but the site was a bad one, presenting no facilities for the construction of a masonry dam.

118. The examination of the Khoro and Kupsa yielded no results. The Keso passes down a considerable volume in high floods, but neither on it nor on the Eerga were there any hills closing in the channel.

119. The Tando drains about $23\frac{3}{4}$ square miles, the water to be retained $=23\frac{3}{4} \times 2,323,200 \times 18.627$, or 1,027,760,448 cubic feet. The slope of the valley is so excessive, being 18.7 feet per mile, that a dam of 50 feet will only keep back the water to a distance of $2\frac{3}{5}$ th miles. I think the whole of the monthly drainage could, however, be retained; the capacity of the channel is $=58,407,360$ cubic feet. The site for the dam was close to the junction of the Tando with the Burrakur.

120. The Churkec was the next river on which a site was discovered. This river rises in Parisnath and falls into the Burrakur 20 miles below the confluence of the Tando. I fixed upon a spot near the village of Chillanga where hills on both sides rise to a considerable height. The drainage area is 87.4 square miles in extent, and consequently the water to be retained will be $87.4 \times 2,323,200 \times 18.627$, or 3,782,169,135 cubic feet. The slope of the bed is 17.55 feet, and consequently the water would with a 70-feet dam be set back to a distance of 4 miles. As relief will also be afforded in a large tributary, which joins a little to the south of the site, I think 2,000,000,000 cubic feet can be held up.

121. On the Gondogo I discovered a site about 2 miles above its confluence where the Barchanga Hill on the left bank faces a hill a little to the north of the village of Longee. A dam of 75 feet would pond the river up $3\frac{1}{6}$ mile, the slope being 23.26 per mile, the area drained $=18.21$ square miles, and the water therefore to be retained is $18.21 \times 2,323,200 \times 18.627$, or 788,006,208, which can be easily done. The channel itself will hold about 92,505,600 cubic feet; the remainder will be provided for in the valley on each side.

122. The Oosree Nuddee is of considerable size, and most dangerous from the nature both of its own bed and that of the Burrakur at the junction. At Ilurdega, a few miles above the confluence, the river is precipitated down ledges of rock at least 50 feet high. Above this the bed is sandy, but no hills appear, and consequently it must be allowed to descend to the Burrakur without interruption.

123. The Bedee River was examined, but no good site was found; the best was to the north of the Doorpaharee Hill; the left bank is nearly perpendicular, but the right sloped gradually upwards to the village of Metrasinghar; the embankment would, however, have been expensive and the quantity of water stored small, so I abandoned the idea of constructing any work in the valley.

124. The Ragheca River near the village of Jurgoodce flows between a hill of the same name and the Bundaro Toongree. These two approached so close together that a dam 100 feet high would only require to be made 690 feet long; the slope of the bed is, however, very great, not being less than 16.09 feet per mile. I was unable to procure any map of the basin, it being out of print, but the drainage area cannot be very large; supposing it to be 30 square miles, the water to be retained would equal $30 \times 2,323,200 \times 18.627$, or 1,298,227,392 cubic feet, and I think a 50-feet dam would keep up 1,000,000,000 of this.

125. The last reservoir will be on the Khoodiya. This river rises in one of the southern off shoots from Parisnath, and running in a south-eastern direction falls into the Burrakur just above its confluence with the Damoodah; it drains 207 square miles, and from its position is a most dangerous and formidable river. The only place where a reservoir could be formed was beyond Govindpore near the village of Assunbunnee: here two hills, the Bhutko Toongree and Mungra Toongree, narrow the valley sufficiently to render the site suitable. The portion of the basin above this is only 61.34 square miles in extent; the water to be retained will, however, be large, viz. $61.34 \times 2,323,200 \times 18.627$, or 2,654,441,856 cubic feet. The slope of the valley is 9.81 feet per mile, and, as the highest dam possible is only $54\frac{1}{2}$, length of the reservoir cannot exceed $5\frac{1}{2}$ miles. I think that the capacity will be about 1,000,000,000 cubic feet; this I calculate to be the case from a cross section I took at a distance of 3 miles above the site of the dam; the area = 4754.71 superficial feet, and the distance across 495, so that the mean depth was only 9.6 feet.

126. The following table gives some additional results :—

Name of Basin.	Maximum height of dam in feet.	Cubic feet of water to be retained.	Area drained above site of dam.	Mean height of dam.	Total length of dam.	Number of miles the river will be ponded up.	Slope of the bed of the river in feet.	REMARKS.
Burrakur ..	54	3,500,000,000	270.16	37.99	700	13	4.17	
Tando ..	50	1,027,760,448	23.75	23.98	2,456	$2\frac{3}{5}$	18.70	
Churkee ..	70	2,000,000,000	87.40	25.82	4,514 $\frac{1}{2}$	4	17.55	
Gondengo ..	75	788,006,208	18.21	35.94	2,221 $\frac{1}{2}$	$3\frac{1}{5}$	23.26	
Ragheea ..	50	1,000,000,000	30	.....	.....	3	16.09	
Khoodiya ..	54 $\frac{1}{2}$	1,000,000,000	61.84	27.80	1,077	5 $\frac{1}{2}$	9.81	

127. The total quantity of water to be retained is about 9,300,000,000 cubic feet, and the drainage area partially controlled about 490 square miles, or under $\frac{1}{6}$ th of the whole basin.

128. I took a large number of cross sections in the different affluents, but they were nearly all so extremely rocky in their beds as to make it doubtful if the formulæ usually used apply.

129. I am now compelled to sum up the results I have arrived at, and leave the completion of this report for a future occasion.

130. The number of reservoirs discovered is 18.

The drainage area partially controlled is 2,260 square miles or $\frac{3}{10}$ ths nearly of the whole basin; but as the water is shed off perhaps with double the rapidity in the upper reaches than it is in the lower, and as the reservoirs are all on the most dangerous rivers, the protection afforded is far greater than this would seem to show.

131. The amount of water which can be held up for subsequent use is 64,362,119,680 cubic feet, or $\frac{1}{8}$ th the greatest monthly flow off; that the Damoodah in 1866 having been 316,526,561,600, and of the Burrakur 68,109,083,560, or 384,635,645,160 cubic feet.

Thus, 64,362,110,680 cubic feet will give an available discharge of 3,266 cubic feet per second for the space of 228 days, *viz.*, from the 1st November to the middle of June, and this does not include the water which would naturally find its way down the rivers in those months.

132. The sites which fulfil the conditions most desirable for the construction of dams, *viz.*, where the valley is broad and deep, contracting at one point, the sides of which gorge are of rocks steep and high, where slope in rear is slight, whilst that in front is steep, and where there is easy access to materials and little or no valuable property to be destroyed, are those in the Haharoo, Bakaroo, Upper Koonaree, Burrakur, Rajheea, and Khoodiya.

133. The number of miles of the rivers which will be held up, and consequently the total length of all the reservoirs, is $109\frac{7}{10}$ ths; the extent of ground covered will be therefore considerably under 200 square miles.

134. The expense of the dams I shall give in my next report, as well as some considerations about other schemes for destroying the effects of the floods in question.

135. The formulæ used in the body of this report are for the quantity of water passed off in the river channel $\sqrt{v} = \frac{9}{10} \sqrt{2 f. d.}$ | where \sqrt{v} = mean velocity in feet per second, f = fall of stream in feet per mile,—and d = the hydraulic mean depth in feet, also as a check— $825 \sqrt[4]{m^3}$ —where m is the area drained.

136. The maps which accompany are not quite complete, as the survey is under revision: the sections necessary to complete the results will be forwarded subsequently.

137. In conclusion, I would advise the construction of gauges in the Damoodah at Ramghur and above the confluence of the Barra-kur; and in the latter river, a short distance above Mahlan; it will also

be advisable to have rain gauges at Burhee, Parisnath, Goond-poor, and Burrakur in addition to those now kept at Hazarcebaugh, Rancee, Bancoorah, Sooree, Burdwan, and Calcutta. I need hardly urge the importance of hourly observations of the great floods at all the river gauges.

From the Government of Bengal, to LIEUTENANT H. W. GARNAULT, R. E.,
—(24th October 1867.)

The Government of India, in letter No. 347. of 16th March 1867, "trusts that the surveys and levels in connection with the Damoodah-Project may be so carried out as to admit of a portion being ready for execution during the next working season ;" observing further, "that it is not necessary, nor even desirable, that the entire system of storage should be arranged for and settled before the works for irrigation are undertaken." But adding, "the works of irrigation and navigation may be undertaken at once on completion of the necessary surveys and estimates to such extent as there shall be water available in the river, or obtainable by a small and easily executed portion of the storage works."

2. To this end it is directed further, "that a selection should be made of a few of the most suitable sites for reservoirs, and detailed designs and estimates for them, together with designs and estimates for Head Works and Canals on both sides of the Damoodah, including one for navigation to connect Ranceegunge with the Hooghly, should be put in hand as speedily as possible ; the necessary surveys and sections being at once proceeded with."

3. The Lieutenant-Governor has therefore resolved to depute you for this special duty, and you will receive the necessary instructions from the Chief Engineer in the Irrigation Department for the preparation of the projects desired in the orders from the Government of India above quoted.

Memorandum of Instructions by LIEUTENANT-COLONEL F. H. RUNDALL,
R. E., *Chief Engineer, Irrigation Department, for the guidance of*
LIEUTENANT GARNAULT, R. E., *on the Project of Canals of Irrigation and Navigation as also of Reservoirs on the River Damoodah,—(24th October 1867.)*

The subject to which your attention was formerly directed was the investigation of the upper reaches of the Damoodah and its tributaries, with a view to the formation of Reservoirs for the purpose of storing and so controlling the excessive floods which annually occur in that river.

2. The information collected by yourself, coupled with that subsequently obtained by Lieutenant Heywood, supplies almost all that is requisite to arrive at an idea of the amount of water to be stored, and the best sites for the formation of Reservoirs.

3. All that will be requisite now, in continuance of those investigations, will be the detailed surveys of one or two at most of those sites; but, before determining finally on them, I wish to accompany you for the purpose of inspecting the localities and examining the features of the adjacent country.

4. Meanwhile the point on which more accurate information is needed, and on which your own report is silent, and that of Lieutenant Heywood appears to me not sufficiently to establish, is the discharge of the Damoodah below the confluence of the Burrakur.

5. Lieutenant Heywood, in paragraph 29, gives a table of discharges based on a Section said to have been taken by yourself, but it is not quite clear whether the volume calculated for the extreme reading of 19.29 on the Ranecgunge gauge, viz., 343,657 cubic feet per second, was made by him or by yourself, as, in the column of remarks, he speaks of calculating "backwards" from that quantity, and so arriving at the slope which was not given in the original section.

6. In your own report the calculation from the Section taken immediately above the confluence gives a volume of 284,388 cubic feet per second as the discharge of the flood of 1866. If this be added to

that of the Burrakur for the same date, as calculated by Lieutenant Heywood, *viz.*, 132,540 cubic feet, a total of 416,928 cubic feet is obtained as the united maximum discharge of the two rivers instead of only 343,657 cubic feet as mentioned above.

7. It is possible that the maximum discharge on each river may not arrive simultaneously at Raneegunge, and, if not, then the discharge at that place would of course be less than the sum of the volumes of the two rivers, but this is scarcely probable, seeing the length of their courses is nearly the same.

8. To determine this point, on which properly hinges all the chief calculations of the correct amount of water to be abstracted from the river, you should take a series of cross sections of the river bed at 2 miles apart, more or less, from the confluence to 4 miles below Raneegunge, carefully selecting the points for the sections, and connecting them by a longitudinal section of the *flood* line of 1866, as well as of the surface of water in the river at the time (being careful to note the daily variation in that water while this longitudinal section is being taken).

9. It will be desirable also to corroborate your previous section of the Damoodah *above* the confluence, and take a fresh set of sections of the Burrakur, both cross and longitudinal, so as to check Lieutenant Heywood's.

10. On the result of these depends the correctness or otherwise of the deductions contained in that Officer's report, and hence it is essential that this point of the maximum discharge should be accurately determined.

11. Having done this and forwarded me the results, you will proceed to take up the subject which is to engage your principal attention, *viz.*, the investigation of the Irrigation and Navigation projects from Raneegunge to the Hooghly on one side and the Roopnarain on the other.

12. As one of the principal objects in view is to provide a line of water communication from the collieries to Calcutta, the off-take of the

canal from the left bank of the river must be taken as near to the coal mines as is consistent with other considerations. The selection of a site for the weir across the river is therefore confined within short limits, and that work must be built within 4 miles either above or below Rancegunge.

Site for Weir.

13. The conditions to govern the selection of a site are,—

1st,—*The width of river*, so as to obtain the *greatest length* of weir possible, in order to discharge the floods with the smallest increase of velocity.

2nd,—*The fall in the bed*. A weir should not be placed too near any sudden increase of fall, such as a rapid, as there the rear water runs off too rapidly and so requires a greater head over the dam, in order to fill the lower basin level with the crest. That is the time when the greatest plunge takes place in the overfall.

3rd,—*The substance of which the bed is composed*. It does not necessarily follow that a rocky site is the best, for it may be so, and generally does happen that the river at such sites is greatly contracted and has a steep fall. The consequence is, that not only is the mass of water carried over any one point on the weir greater, but it is carried at a much higher velocity. The momentum and therefore the destructive power of the water is thereby immensely increased, the rates of such increase being as the *square*, so that, if the momentum in one case were 5, and in another 10, the force which the relative works would have to withstand would be as 25 to 100, or four times as great, and therefore the weir built on the rocky site might possibly require to be built four times as strong as one on a sandy bed; *ceteris paribus*, however, of course, the harder substance is to be preferred.

4th,—*The substance of the banks*, not so much with a view to the protection of the flanks of the weir as to the cost of excavating the off-take of the canals; for, if rocky or very high, the labour and expense of excavation may be so great as seriously to affect the remunerativeness of the projects.

5th,—*The proximity of the material necessary for the construction of the weir on which mainly depends its cost*.

6th,—*The general direction of the river*. It being desirable in wide rivers to select a straight reach, so that the approach to, and departure from, the weir may be affected as little as possible by counter-currents.

14. The height and form to be given to the dam must depend on the three first conditions, coupled with that all-important one, the volume discharged in the highest known flood, the ascertaining of which, as directed for your first investigation this season, is therefore equally necessary for this as well as for the Reservoir project.

15. Precise instructions on this head then can only be given after the information on the other points has been procured.

16. While personally prosecuting the investigations for the weir,
Canals. your Assistants should be employed
in taking the preliminary cross sections
over the country which the proposed canals are to traverse.

17. On the left bank, if there are no series of bench marks *known* and well *defined* on the river bank itself, the line of railway will form an excellent base on which both to check and to connect the series of cross levels, which, in the first instance, should be taken at two miles apart. The datum to which all the levels are to be referred should be the level of mean-sea, as determined on the Howrah Dock site, to which it is believed all the railway levels are also referred.

18. The point to which the canal should tend after leaving the river is the watershed common to the Damoodah and the nullah which runs between it and the Adjai.

19. The level plus mean-sea of the bed of the river, say four miles above Rancegunge being known, the cross levels should be taken until that level is reached, or until the watershed is crossed, where the level of the latter may be lower than the governing point in the bed of the Damoodah. Beyond the point where the Damoodah turns to the south, the limits of the cross levels will be the Kana Nuddee, and the Boro or Baollea Nullah to the north of the Grand Trunk Road.

20. These levels, having been carefully checked and laid down on the 1-inch to the mile map, will indicate the general course which the Main Canal should follow to Calcutta, as well as the main branches of it, and the general levels of it being also thus determined, the actual line may then easily and quickly be levelled and surveyed.

21. The dimensions to be given to this canal will depend somewhat on the area of ground it will command, but the principle which should govern

Dimensions of Canal.

its projection is the area to which water can be conveyed during the monsoon months when the river has an abundant supply ; for though the rainfall at Burdwan averages 60 inches during the year, yet 12 inches of that quantity falls in months other than that in which the main crop of rice is grown, leaving 48 inches for the five months from June to October inclusive, and during these five months that quantity is often very unequally distributed ; for instance in the month of

June	4	years out of 8 it varied from 6	to 9	inches.
July	1	ditto „ it was only	9	„
August	3	ditto „ it varied from 5·80 to 7·20	„	
Sept.	6	ditto „ „ 4·80 to 7·95	„	
Oct.	6	ditto „ „ 0·00 to 3·60	„	

22. The two last months are those in which the great crop runs the greatest hazard from drought, and therefore the canal should be designed to supply as large an area as possible so as to meet such a contingency.

23. To adapt it for navigation purposes also, it will have to be furnished with locks so arranged that if

Navigation.

at any time it should prove necessary to reduce the canal to still water, the lower lock should be at such a level as to keep a depth of 5 feet on the lower sill of the lock immediately above it.

24. The depth during monsoon supply should be 7 feet, and the fall not greater than 6 inches per mile, gradually reduced to dead level towards the last reach, in proportion as the areas to be irrigated abstract the supply and so leave less to be conveyed onwards.

25. These are details, however, which cannot be adjusted until the actual course of the canal has been determined.

26. The area to be irrigated is that contained between the river and high ground north of the Railway as far as Burdwan, and from thence between the Kana Nuddee and Baollea Nullah. Half the area

commanded may be assumed as likely to eventually take water. That area is about 800 square miles, which at 500 acres per square mile amounts to 400,000 acres, half of which or 200,000 acres may be provided for at the rate of one cubic yard per hour per acre, or, in other words, the canal should be designed for 1,500 cubic feet per second.

27. In order to ascertain the minimum quantity to be depended on for the main crop, the quantity passing Raneegunge this year on the 30th instant should be measured, and the readings of the gauge, for as many years as available, be compared with that of the present year, and calculation of the volume deduced therefrom.

28. The volume passing on the 1st and 15th of each month from November to June should also be regularly measured, in order to see to what extent it may have to be supplemented from the Reservoirs.

Volume in summer months.

29. The terminus of the canal should be made in one of the tidal khalls supplied by the Hooghly; probably that at Bally will be the most convenient.

30. For the canal from the right bank the same course should be pursued as regards the cross sections, but which may perhaps be limited to the area between a line passing through Kishtonugger to Burdwan, as the canal can only skirt the high ground as far as the former place. The entire area comprised between the two rivers to which water may be led is about 500 square miles, and may contain 250,000 cultivable acres. The canal may therefore be taken with a fall of 6 inches per mile as far as Kishtonugger, and from thence the levels will shew where it should strike the bank of the Dalkissur or Roopnarain, and probably for that distance it should be designed as only a navigation line, leaving the irrigation to be distributed by branch channels taking off at Kishtonugger, while the navigation line is carried on to opposite Ghatal, or wherever the tides serve sufficiently to admit of boats passing from the canal into the river at all seasons of the year.

Canal from right bank.

31. All details regarding the distributary channels must necessarily be left for future examination. Their *general* direction will be sufficiently indicated by the series of cross levels.

32. During your investigation, you are to take every opportunity of obtaining information from every available source, Revenue Authorities, Zemindars, Planters, Ryots, and others, relative to the crops at present cultivated ordinarily, and those which an ample and certain supply of water would admit of being undertaken.

Statistical information.

33. Of the yield of such crops, maximum, minimum, and average, and the causes of variation, whether arising from description of soil, excess or scarcity of water, particular notice should be taken, also of all crops at present irrigated, partially or regularly, by river water or from wells, the cost of such irrigation, the quantity of water given to different crops, and the height to which the water has to be raised. You will also be careful to ascertain the feeling of the cultivators generally regarding irrigation, and explain to them the benefit that will be derived by the application of the muddy water of the Damoodah during the freshes as a fertilizer, though this is a point to which every cultivator is alive.

34. All information on this head to be given in English measurements, areas to be given in acres, and weight of produce in lbs. Indian weights, measures, and nomenclature to be avoided as far as possible.

35. All particulars likewise regarding the traffic which may be calculated on passing by this canal should be carefully collected. It will consist of most of what is now conveyed by boat down the Damoodah, also probably some of the coal now taken by rail, and much, if not all, of the ordinary traffic that now passes along the Grand Trunk Road. It is believed also that the present means of conveyance by rail and river are insufficient for the demand on the collieries, so that there may possibly be a considerable increase in the quantity of this article. Information on this head will probably be procurable from the Managers of the coal mines. The present cost of transport by road, rail, and river should be ascertained.

36. The quantity of work to be executed will, roughly stated, be about 750 miles of cross levels on the left bank and 150 miles on the right bank, with perhaps 300 miles of longitudinal sections for main lines

Amount of work to done:

and branches, say 1,200 miles in all. This should be accomplished at the rate of 300 miles per month, and, allowing only 75 miles per man, will require four levellers, but in flat open country, such as that wherein most of the cross levels will have to be taken, a fair leveller should accomplish 4 to 5 miles per day. By the end of February, therefore, this project should be ready for submission.

37. As soon as all the information has been collected, the plans will best be drawn up after receipt of detailed instructions from myself, which will be best and most quickly given to you personally when you bring your survey to Calcutta.

38. For such further investigation, surveying, or levelling as may be needed connected with the Reservoir project, additional hands must be procured.

39. An estimate of the probable number and expense of the establishment you will require should be framed by you at once, and any qualified persons you know of, or may make application for employment under you, will be immediately brought to the Lieutenant-Governor's notice with a view to their entertainment.

40. Your correspondence will, in order to save time, until further orders, be conducted direct with the Chief Engineer.

From the ~~Government~~ Government of Bengal, to the Government of India,—(dated the 30th May 1868.)

I am instructed to forward the accompanying two Reports* with Plans received from Lieutenant Heywood, R. E., who was deputed to continue the explorations commenced by Lieutenant Garnault on the feeders of the Damoodah, with a view to the discovery of sites for Reservoirs, whereby the floods of that river might be controlled.

2. The contents of these Reports have been analysed in the accompanying Note by the Chief Engineer of Irrigation, who, while assenting to many of the various conclusions arrived at, considers that the total quantity of water recommended to be stored and calculated at 7 $\frac{7}{10}$ ths

* NOTE.—One of these Reports only is printed in this "Selection," as the other (adverted to in the Chief Engineer's Note, paragraphs 40 et seq.) refers only to works visited by Captain Heywood in Europe.

of the maximum monthly rainfall is unnecessarily large, and that sufficient control over the river would be obtained if provision were made for storing three-fourths of a *maximum* flood, for two such floods rarely occur in the same season, and only at considerable intervals.

3. By Lieutenant Heywood's investigation the existence of sites for Reservoirs, more or less favorable, has been clearly established, and, apart from the remoteness of the localities in which they are situated, there appears to be no reason to question the practicability of their construction.

4. The Lieutenant-Governor, however, believes that the principal difficulty involved, *viz.*, the concentration of labor, may be overcome in this instance as easily, if not more so than in other localities, inasmuch as the scene of operations would not be far from the great labor markets of Chota Nagpore and Sonthalia, and he would therefore recommend that a commencement be made with such of the Reservoirs as present the greatest facilities, and can be executed at a moderate cost, more especially as the Chief Engineer has pointed out the absolute necessity for some water being stored in connection with the proposed canals from the Damoodah now under investigation.

5. For this purpose three sites on the Damoodah and two on the Burrakur seem well adapted for such a commencement to be made, especially as the water stored therein, calculated at 17,500 million cubic feet, would, when held back, not only exercise a most perceptible effect on the floods, but also be immediately re-productive in supplying the Canal from Raneegunge to Calcutta at a time when there would be little or none available in the river.

6. The Lieutenant-Governor is all the more anxious to see this experiment tried, as the floods of the Damoodah are still a subject of great difficulty, which the measures hitherto adopted cannot be said to have practically solved. In your letter No. 347. dated 16th March 1867, the Government of India observed that "it would not be necessary, nor even desirable, that the entire system of storage should be arranged for and settled before the works of irrigation are undertaken;" but added "that the selection should be made of a few of the most suitable sites for Reservoirs, and detailed designs and estimates for them, together with

those of the head-works and canals from the Damoodah, should be put in hand as speedily as possible." The Lieutenant-Governor therefore proposes to have the surveys and estimates made for the Reservoirs enumerated in paragraph 5, as forming a necessary adjunct to the Canal Project, and at the same time offering an opportunity of testing to a not unimportant extent, and without additional expense, the principle of restraining the floods.

7. The Lieutenant-Governor considers the Reports reflect great credit on Lieutenant Heywood, and that he is deserving of special commendation for the ability and energy he has displayed in carrying out the investigation entrusted to him.

Note by LIEUTENANT-COLONEL F. H. RUNDALL R. E., Chief Engineer to the Government of Bengal, Irrigation Branch, on the Reports submitted by LIEUTENANT HEYWOOD, R. E., in connection with his explorations for Reservoirs on the River Damoodah and its affluents.

Of these two Reports, the one contains the results of an examination of the basin of the Damoodah, with a view to the possibility of controlling its floods by the construction of a series of Reservoirs on its several feeders; the other, an account of an inspection of certain existing Reservoirs on the Continent of Europe.

2. The first Report commences with a discussion of the several points of rainfall, evaporation, absorption, and the consequent proportion which drains off the country and causes the flood.

3. Statements of the rainfall for eight years in Calcutta, Burdwan, Bancoorah, Hazareebaugh, and Ranchee are appended, and exhibit the following as the mean yearly fall:—

Calcutta	..	..	..	69·57
Burdwan	...	..	...	59·88
Bancoorah	..	..	..	54·70
Hazareebaugh	..	..	...	75·52
Ranchee	..	...	..	39·28

4. These places are perhaps scarcely sufficiently numerous to obtain an accurate idea of the mean yearly rainfall over the whole basin,

but Lieutenant Heywood's deductions are probably not far from correct. He assigns a mean between the fall at Hazareebaugh and Ranchee, or 57·40 inches over an area of 2,100 square miles to the south of the plateau, and for the 1,200 square miles to the confluence of the Burrakur he takes the quantity registered at Bancoorah, also 57·40, while for the Hazareebaugh plateau itself, an area of 900 square miles, he allows the full fall registered at that place, *viz.*, 75·52 inches.

5. For the basin of the Burrakur, or 2,700 square miles, he assumes a mean between that of Hazareebaugh and Bancoorah of 66·44 inches.

6. From the above he deduces the following as the mean rainfall during each of the undermentioned years:—

1860	..	..	..	39·55	Inches.
1861	..	..	..	61·97	„
1862	..	..	..	73·65	„
1863	..	..	..	72·79	„
1864	..	..	..	40·61	„
1865	..	..	..	65·85	„
1866	..	..	..	77·18	„

7. The greatest *monthly* rainfall occurred, *viz.**—

At Hazareebaugh in August 1862	..	31·13	Inches.
„ Ranchee „ July 1864	..	16·90	„
„ Bancoorah „ „ 1862	..	22·10	„
„ Burdwan „ „ 1861	..	24·95	„
„ Calcutta „ June „	..	26·44	„

8. The greatest *daily* rainfall noted was—

At Hazareebaugh 25th September 1863	..	13·0	Inches.
„ Bancoorah 22nd „ 1860	..	9·20	„
„ Burdwan 26th October 1868	..	8·70	„
„ Calcutta 2nd July 1866	..	4·20	..

9. The first point noticeable in the above statements is the extreme *variation* of the annual rainfall, and the next, that in no two places in the catchment basin does the greatest monthly or daily rainfall ever occur simultaneously. It has been supposed that the discharge

* See Appendix II, at the end of this Volume.

of the Damoodah flood has reached 600,000 cubic feet per second, and that it has been the result of a rainfall of 13 inches over the entire catchment basin. Such a fall, supposing that $\frac{2}{10}$ ths of it were to run off the country, would amount roughly to $7,000 \times 28,000,000 \times \frac{2}{10} = 145,300$ millions cubic feet, and require the full discharge of 600,000 cubic feet per second over a period of 67 hours; whereas the Damoodah rarely if ever remains at its *full* height for more than three hours. It is clear, then, that whatever may be the maximum discharge of the Damoodah, it cannot be the result of any such fall of rain as 13 inches over its whole catchment basin.

10. The experiments made regarding evaporation do not have much bearing on the question, as whatever may be the total amount evaporated during the year, it would not necessarily affect the quantity of water which might run off the basin in any particular burst of rain during the height of the monsoon; but there are other points which do materially affect it, and amongst them is the geological formation of the basin and the absorbing power of the rocks composing it.

11. The fact that the floods of the Damoodah are violent and rapidly carry off the rainfall, while during the dry season a mere dribble of water passes down the river, indicates that the rocks contained in its basin have very little power of absorption, and that therefore the surface drainage bears a large percentage to the rainfall. Lieutenant Heywood next gives a tabular statement of the discharge of the Damoodah for various heights on the gauge at Raneegunge, where the spill of the river is inappreciable. This statement is deduced from sections taken by Lieutenant Garnault, and they make the maximum flood, marking 19.29 on that gauge, to carry 343,657 cubic feet per second. From this table he has compiled a statement shewing a comparison between the water shed off and the rainfall, and arrives at the result that about $\frac{2}{10}$ ths of the whole yearly rainfall passes off through the drainage channels. As far as can be judged, this result appears sufficiently correct for all practical purposes.

12. More recent sections, taken very carefully between Raneegunge and the confluence of the Burrakur, give for the maximum

discharge of the river 323,000 cubic feet per second, without any allowance for the displacement of the sand.

12. But Lieutenant Heywood states he has verified observations previously made by Lieutenant Granault and others regarding an extraordinary flood which occurred in 1823, and which, if the traditional flood marks are correct, he calculates must have reached the enormous quantity of 3,423,000 cubic feet per second. Adopting, however, Colonel Goodwyn's observations instead of his own, he makes the discharge in that year to have reached 1,605,000 cubic feet per second, and from that argues that Colonel Dickens's assumption of a maximum flood being 600,000 cubic feet per second "is not above the truth."

14. A cycle of nearly 50 years, however, has now passed without an approximation to anything like the traditional flood of 1823, and the careful sections of late years, when the height of extraordinary floods must be tolerably fresh in the recollection of the villagers living on the banks, cannot make the extraordinary flood of 1866 even approach within $\frac{1}{3}$ of the quantity assumed in Colonel Dickens's memorandum of 1853. I confess to feeling sceptical as to the probability of the large figures above quoted, as when reduced to the test of carefully kept registers of rainfall, it would seem to be beyond the bounds of possibility, and contrary to the laws of storms, that the enormous rainfall, from which those above-mentioned traditional floods could only have resulted, should have taken place *simultaneously* over an entire catchment basin of 7,000 square miles.

15. Though the period over which the rain registers have been kept is small, yet still within that time memorable floods have occurred, and a comparison of the rainfall with that of the water discharged by the river will give, though perhaps not a perfectly accurate result, yet a sufficiently near approximation, to show how the rain is distributed, and the quantity that may be assumed as an average fall within a given time over the whole basin.

16. The area of the entire basin above the confluence with the Burrakur is estimated at 6,300 square miles, equivalent to 176,400 millions square feet. Turning now to the particulars of the ten floods

which have of late ^{years} years occurred in the Damoodah, it is found that the gauge at Raneegunge stood highest in the following years :—

1859	...	...	...	18' 0"
1860	...	...	...	18' 0"
1863	...	...	...	18' 4"
1865	...	...	...	20' 0"
1866	...	...	...	19' 6"

17. The rainfall for 1859 is unfortunately imperfect. In Lieutenant Heywood's Report the fall at Ranchee has been omitted, while that at Hazareebaugh appears not to have been procurable. The omission of the first is supplied from the selection of Government Records for 1859, and a comparison of the fall at Ranchee and Hazareebaugh respectively, in months subsequent to the occurrence of the flood, shews that there is generally twice the amount of rain at the latter place. On this assumption the rain which produced the flood of 1859 was distributed as follows :—

DATE.			Edilpore Gauge.	Raneegunge Gauge.	RAINFALL.				Average over the whole basin.	Proportion drained off at 7.10.
Year.	Month.	Day.			Ranchee.	Burdwan.	Bancoorah.	Hazareebaugh.		
1859 ...	July ...	25th	Ft. Ins. 6 0	...	0.20	0.50	1.40	0.40	0.83	0.58
		26th	6 2	...	0.70	0.80	0.00	1.40	0.97	0.68
		27th	5 0	...	5.50	1.80	3.30	11.00	5.40	3.78
		28th	14 6	18' 0"	0.30	0.00	0.00	0.60	0.22	0.15

The following description is given of this flood :—

18. At Edilpore the river commenced rising from a level of 5 feet very early in the morning of 28th July, and at noon attained its greatest height of 14' 6", which it maintained for three hours. At 3 p. m. it began to subside and fell one foot by 6 o'clock the same evening, and the following day at noon it was down to 10' 6" on the gauge.

19. The number of hours therefore the Dimoodah was above an inundating level was—

Between 27th and 28th	...	...	$11 \frac{7}{19}$ hours.
28th „ 29th	...	...	24 „
„ 29th „ 30th	...	...	$4 \frac{4}{5}$ „

40 hours.

20. From the above it appears that the flood remained at its greatest height for only three hours. The table of discharges gives for that height of 18 feet a volume of 296,265 cubic feet per second; or a total quantity during the three hours of $296,265 \times 3,600 \times 3 = 3,199,662,000$ cubic feet. This quantity, divided by 176,400, the area of the whole basin, gives a rainfall of .0715 of an inch per hour, or of 1.79 inches during 24 consecutive hours. The average rainfall in the same time for the three days previous to the flood shews 2.4 inches, or about .60 of an inch, or $\frac{1}{3}$ rd more in excess.

21. The flood of the following year lasted 60 hours, and is calculated to have discharged during that time 57,302,587,906 cubic feet. It reached the same height, viz., 18.0 on the Raneegunge gauge, but the exact time for which it stood at that height does not appear to have been registered. The total quantity calculated to have passed down the river during the flood, however, is equivalent to 3.9 inches draining off, or 5.85 of rainfall. From the table in paragraph 45, assuming similar relative proportions between Ranchee and Hazareebaugh as before, the registered rainfall amounts to 3.915 inches, or about .062 of an inch per hour. The calculated discharge divided by 60, the number of hours through which it lasted, gives .98 of an inch per hour.

22. Passing on to the flood of 1863, it is calculated that the discharge between noon on the 24th to morn on the 27th amounted to 63,800,000,000 cubic feet, or to 886,000,000 cubic feet per hour, equal to a rainfall of .09 of an inch per hour, or of 2.16 per day. The registered rainfall gives an average of 2.09 inches.

23. The readings for the year 1865 were defective, but from those of the next recent flood of 1866 the discharge is calculated to have reached 59,170,586,400 in 55 hours, or 1,075,823,390 per hour, equivalent to a rainfall of $\cdot 1152$ of an inch per hour, or $2\cdot 76$ per day. The registered rainfall, omitting Ranchee, gives $3\cdot 63$, or, inclusive of that place, only $2\cdot 83$ inches, which is remarkably corroborative.

24. Tabulating the above, the comparison between the registered daily rainfall producing great floods, and that calculated from the discharge, is as follows :—

	1859.	1860.	1863.	1866.
Registered average fall	2·4	1·24	2·09	2·83
Calculated ditto ...	1·79	2·34	2·16	2·76

25. For the hourly rainfall the comparison shows :—

	1859.	1860.	1863.	1866.
Inches.				
By rain register ...	0·100	0·052	0·087	0·118
Calculated ditto ...	0·075	0·098	0·090	0·115

26. Though this comparison does not shew results perfectly accurate, yet they are sufficiently mutually corroborative to establish the fact that the heaviest floods of late years, regarding which tolerably careful observations have been taken, are due to no greater distributed rainfall than three inches per day over the whole basin ; that though in individual localities a much greater fall may be experienced, yet such is limited in extent, and its effects as to floods are mitigated by the respective distances which the water has to travel before it reaches Raneeunge ; and that as the actual observations of late years are probably more correct than the deductions from the limited observations of former years, they serve to throw great doubt on the possibility of such an extreme flood as is said to have occurred in 1823.

27. The flood of 1866 is particularly instructive as to the manner in which the rainfall, in successive portions of the basin, arrives at a given place on the river.

28. The observations for that flood were made at Edilpore.

29. On the 30th June 4.50 inches fell at Bancoorah. On the morning of 13th July the river *commenced* to rise, the gauge showing at 10 A. M. 11 feet 6 inches. By evening it read 14 feet. During the 1st, 4.80 inches more fell at Bancoorah, 5 inches at Burdwan, and 9 inches at Hazareebaugh, thus showing the direction in which the storm was travelling.

30. On the 2nd July the river gauge still read 14 feet, thus shewing that the supply was kept steady by the same fall of which that at Bancoorah was the measure. In the afternoon there was a slight fall of 6 inches in the river, indicating that the source which had supplied the first flood was exhausted, *i. e.*, the rain had ceased, but by 1 A. M. of the 3rd, or 7 hours afterwards, the gauge had risen to 15' 0" or 18 inches higher, thus shewing that the rain which had fallen at Hazareebaugh, the most distant part of the watershed, had only *then* begun to arrive. It remained at this height, however, for a very short time, for in 9 hours afterwards it had fallen 4 feet, thus proving that the area over which the large quantity of 9 inches had fallen must have been comparatively limited.

31. Comparing this with the readings of the Burrakur, it was evidently the rain which had fallen on the catchment basin of that river which caused the sudden rise to 15 feet on the Edilpore gauge, as the Burrakur rose, from 2 P. M. to 7 P. M. on the 2nd July, from 13.58 to 16.25, having at 7 P. M. of the *previous* day read only 10.66, and on 7 P. M. of the *following* day had fallen to 8.50. The Barrakur had thus, at the height of its flood, added, according to the table given in paragraph 35 of Lieutenant Heywood's Report, 80,422 cubic feet per second to the volume of the Damoodah.

32. The relative heights on the Edilpore and Raneegunge gauges are by no means clearly definable from the tables, as there are several manifest discrepancies; but as far as it is possible to judge, a height of 13 feet 6 inches at Edilpore corresponds with 17 feet 6 inches at Raneegunge. The calculated volume passing at the latter place for that height would be 280,800 cubic feet per second, to which if 80,422 cubic feet be added, it would give 361,222 cubic feet as the discharge of the river due to a height of 19 feet 6 inches on the Raneegunge gauge, which corresponds fairly with the amount given in the table against a height of 19.29.

33. The two conditions which render a flood destructive are, first, the actual volume of water passing down the river; and, secondly, the length of time it continues to pass.

34. In paragraph 47 of Licutenant Heywood's Report it is stated that when the river is below 10 feet on the Edilpore gauge there is no overflow, and that the volume then passing measures 237,660 cubic feet per second.

35. The greatest discharge measured on the Raneegunge gauge was in 1866, and must have been 361,222 cubic feet per second. The greatest total quantity which passed during one day was 25,699 millions nearly, and the total discharge of the whole flood 59,171 millions. The quantity discharged at Edilpore during the same period amounted to 47,271 millions; so that, if the difference, or 11,900 millions, could have been held back for three days, the floods would have passed off without injury. It is the possibility of thus holding back the flood by means of Reservoirs judiciously situated that has been the aim of Licutenant Heywood's investigations. From the calculations just given, it would seem that the quantity of water to be retarded is comparatively small. A Reservoir to contain 12,000 millions cubic feet, supposing the average depth of the water to be 40 feet, would only require an area of 300 millions square feet, or 11 square miles, less than the area of many tanks in Madras; but a

single Reservoir would not answer the purpose, and were it sufficient, it would be better to distribute the same quantity of storage amongst three or four Reservoirs, so as to catch a relative proportion of the rain as it travelled over the respective portions of the catchment basin.

36. It would not, however, be safe to calculate on the retardation only of the exact quantity that would appear to be necessary to retain the flood within the natural banks of the river, for there is another element to be taken into consideration, and that is the intervals between successive floods. This subject is discussed by Lieutenant Heywood in paragraphs 61 and 71, where he shows the shortest spaces of time which so elapsed in July 1862, in which month there were eight freshes, the intervals on three occasions being only one day, on one occasion two days, two occasions three days, and on one occasion five days, but of these floods only three reached the height of 11·0 on the Edilpore gauge, and at intervals of 8 and 14 days respectively, which would have allowed abundance of time for the Reservoirs to have emptied themselves against the arrival of the next flood.

37. As a precaution, however, Lieutenant Heywood proposes to retain $\frac{7}{10}$ ths of the greatest observed monthly rainfall, or 17 inches for the whole basin, and nearly 22 inches in the affluents flowing from the Hazareebaugh plateau. At this rate the total quantity of water to be stored would amount to the large quantity of 233,233 millions cubic feet.

38. This quantity, I am of opinion, would be unnecessarily large, unless of course it can be made available for purposes of irrigation afterwards. For simply retarding or regulating the floods, it would be sufficient to provide for the storage of $\frac{3}{4}$ ths of the quantity which is known to have produced a maximum flood like that of 1866. The average over the whole basin during the three days that the rain then lasted was under 6 inches, $\frac{7}{10}$ ths of which would be 4·2 inches, so that

the quantity drained off would amount to $\frac{6,300 \times 28,000,000 \times 4.2}{12} = 61,740$ millions, $\frac{2}{3}$ ths of which would be 46,300 millions. It is impossible to say what the actual cost of storage would amount to, but if it did not average more than Rupees 50 per million cubic feet, a liberal allowance where water is stored on a large scale in this country, the total cost would be Rupees 23,15,000, and the interest at 10 per cent, Rupees 2,31,500, or Rupees $1\frac{1}{2}$ upon the the acreage which the proposed canal from Raneegunge will irrigate, whereas the above quantity would be sufficient for the irrigation of about 500,000 acres of coldweather crops.

39. The result of Lieutenant Heywood's investigation was the discovery of 12 sites for Reservoirs on the Damoodah more or less favorable, the aggregate capacity of which is estimated at 55,000 millions of cubic feet, and of six sites on the affluents of the Burrakur aggregating 9,300 millions cubic feet.

40. Of the former, however, only eight are favorable as far as the slope of the river is concerned, and in all of them the length of dam is greater than desirable. The total length of dam being 41,845 feet, the maximum height of these Reservoirs varies from 45 to 130 feet, and the mean height from 10.74 to 68 feet.

41. A reference to the subjoined table will show at a glance the sites which are most favorable, as also the cost in each case of storing 1,000,000 cubic feet, varying, as will be seen, from 11.5 to 94.4 Rupees. The two last sites are by no means favorable, owing to the great length of high dam which appears to be necessary. The prices affixed are based on the cubic contents of each lineal foot and a liberal rate per 1,000 cubic feet. The multiplication of columns 7 and 11 gives the value in column 12, which divided again by the quantity in column 4 furnishes the rate in column 13.

Table of Reservoir sites on the Damoodah and Burrakur and their Affluents, shewing the dimensions of the Dam, contents of Reservoir, and probable cost of Earthwork per million cubic feet of water stored.

DAMOODAH.

1	2	3	4	5	6	7	8	9	10	11	12	13
Number.	NAME OF BASIN.	Maximum height of Dam in feet.	Cubic feet of water to be retained.	Area drained above site of Dam.	Mean height of Dam.	Total length of Dam.	Number of miles of pond.	Slope of bed of river in feet.	Mean cubic contents per foot run of Dam in cubic feet.	Rate per foot run.	Total cost of earth-work to Dam.	Cost per million cubic feet of water.
1	Mahan	45	500,000,000	32.30	10.74	2,244	9.5	17.98	522.5	30.0	6,732	13.4
2	Damoodah	100	8,000,000,000	132.42	48.11	3,952	10.7	9.30	6,224.0	50.0	1,87,600	24.7
3	Gurhee	80	7,000,000,000	135.00	24.47	10,952	9	8.84	2,180.0	12.0	1,31,424	18.8
4	Suhree	100	1,582,120,000	47.0	...	...	8	7.125	4,800	...	...	...
5	Haharoo	110	8,000,000,000	250.0	68.19	1,556	11	8.54	1,282.0	120	2,22,720	27.8
6	Bakaroo	130	3,500,000,000	225.0	60.0	1,725	12	10.73	11,569.0	100.0	1,72,500	31.3
7	Kharree	105	4,500,000,000	448.55	49.86	3,041	4.7	22.14	7,250.0	60	1,82,460	40.0
8	Ditto	79	4,000,000,000	395.95	30.37	2,231	5.5	14.13	3,100	20	41,620	11.19
9	Ditto	100	3,000,000,000	309.66	45.60	1,089	4.2	23.75	6,200	50	54,450	18.18
10	Jumooness	100	5,000,000,000	349.64	33.33	7,132	8	12.56	3,570	25	1,73,300	35.96
11	Ditto	100	6,000,000,000	183.96	54.42	7,553	10	10.0	8,900	75	6,66,475	94.4
12	Gowaie	46	600,000,000	183.96	unknown	7,553	2.8	16.18	...	...	...	...

BURRAKUR.

1	Burrakur	54	3,500,000,000	270.16	38	700	13	4.17	4,370	30	21,000	6
2	Tando	50	1,027,760,500	23.75	24	2,458	2.75	19.70	1,820	12	29,722	28
3	Churkee	70	2,000,000,000	87.40	26	4,515	4	17.55	2,200	15	67,725	33.86
4	Gondengo	75	758,000,000	18.21	36	2,222	3.2	23.26	3,960	30	66,660	84.0
5	Raghees	50	1,000,000,000	30	...	...	3	18.09	...	...	...	...
6	Koodiya	55	1,000,000,000	61.34	23	1,077	5.5	9.81	2,520	18	19,886	19.38

42. Of the six sites on the Burrakur only the first and sixth are favorable, the former particularly so, owing to the dam being so short. The first, third, and sixth might, however, be undertaken, as the average cost would not amount to more than 1,10,000 Rupees for 6,500 millions cubic feet, or only Rupees 17 per million. The cost per running foot of dams on the Burrakur will of course be smaller, as so much less height of dams is necessary than on the Damoodah.

43. As far then as the existence of sites and the probable expense of construction of the Reservoirs are concerned no obstacles seem to exist. The real difficulty in the matter is the practicability of constructing such works in remote localities, away from any population, and in an unhealthy climate.

44. With proper arrangements, however, there is no reason why these difficulties should be insurmountable. At all events it will be desirable to make a commencement with two or three Reservoirs, the bunds of which are short and so capable of being constructed in a single season.

45. For this purpose I would recommend Nos. 1, 3, and 8 in the Mahcan, Gurhee, and Konaree affluents of the Damoodah and Nos. 1 and 6 on the Burrakur being regularly surveyed and estimated for. The maximum heights of the dams on the first-named are 45 and 80 feet respectively, while the mean heights are only 10·74, 24·47 and 30·37. The total estimated capacity is 12,500 millions cubic feet.

46. The maximum height of the two Reservoir bunds on the Burrakur is 54 feet, while the mean heights are 38 and 28 feet respectively, and their estimated contents 4,500 millions cubic feet.

47. The aggregate of the five Reservoirs will thus be 17,000 millions cubic feet, or rather more than $\frac{1}{4}$ th of the whole quantity of water shed off in a great flood like that of 1866, sufficient to have lowered the level of the river to within its natural banks at Edilpore and so prevented any destructive effects.

48. The cost of storing the above quantity of 17,500 millions, even at a rate of Rupees 50 per million, will be only Rupees 8,75,000, while the water will be immediately available for irrigating during the cold weather the area of 200,000 acres commanded by the Raneegunge

Canal, and so become at once remunerative. Indeed, in order to make this latter scheme complete, it is absolutely necessary to provide for storage, otherwise there will not be sufficient water in the river to keep the canal deep enough for navigation. Even by January the volume of the Damoodah falls to below 300 feet per second, and is still further reduced by March to less than 100 feet. Such being the case, the two projects must be so far taken up simultaneously. By commencing with the Reservoirs which I have selected above, we shall not be undertaking anything beyond what has already been done, as there are several tanks in various parts of the Madras Presidency of equal if not of much greater capacity.

49. Lieutenant Heywood's second report will now properly come under notice. It contains detailed descriptions of the principal Reservoirs inspected by him in France and Spain. The particulars, though very interesting and useful wherever similar works may have to be undertaken, are not of practical application to the construction of Reservoirs in this country, the dams of which, with only one exception, coming within my own knowledge, are all built with earth and not with masonry.

50. The sites of the works described by Lieutenant Heywood are all very unfavorable, being selected near the sources of the respective rivers, where the slope of the bed is very great. Probably these sites were forced upon the Engineers who designed the Reservoirs from a variety of imperative circumstances; but the result is, in the only instance where the outlay is cited by Lieutenant Heywood, that the cost of storage is most excessive, *viz.*, in the Rochetville Reservoir, which is stated to have cost £64,000.

51. Though its capacity is not given, yet the mean annual discharge of the river "Turens" is stated to have been 17·6 cubic feet per second for eight years. If it is this quantity which is stored, the capacity of the Reservoir would be about 550 millions cubic feet, and the cost upwards of Rupees 1,160 per million, or less than 900 cubic feet per Rupee, a cost which is utterly out of the question for India.

52. It is not, however, necessary for us to go to European countries to learn the art of constructing Reservoirs. The natives of India

are much older Engineers in this respect than those of any other country, and the magnificent tanks studded throughout the Peninsula in the Carnatic, Mysore, and Hyderabad territories afford examples of structures of every variety and description, while their existence after so many centuries is the best test of the correctness of the principles on which they have been constructed. The point, however, on which more experience is really required, is that of the arrangement for working sluices under heavy head of pressure. The details given in some of Lieutenant Heywood's plans will be useful in this particular.

53. It is necessary to notice that the rule regarding waste weirs, quoted as having been issued by Mr. Rawlinson after the failure of the Sheffield Reservoir, could not be safely followed in this country where the Reservoirs are on so much larger a scale, and exposed to terrific squalls of wind, which in a few minutes not only raise very high waves but pile up the water from the opposite extremity of the Reservoirs against the embankment. In a Reservoir 75 feet deep and 6 or 7 miles in length, it would not be safe to have the crest of the weir less than 15 feet below the top of the bund, while its length should be sufficient to discharge the extreme flood of the river across which the Reservoir is thrown; so that, in the event of its being overtaken by a flood when brimfull, there would be no danger of having its surface level further raised. These points, however, are matters of detail to be arranged in each project at the time that it is designed.

54. I would only add by way of conclusion that Lieutenant Heywood's two Reports, besides being replete with great professional ability, bear the evidence of much patient and careful thought. They are certainly the result of much energy and labor bestowed on investigations in an isolated and difficult part of the country, and at the sacrifice of all personal comfort, and have fairly earned for their author special commendation from the Government.

Report by CAPTAIN H. W. GARNALT, R. E., on the Project for a Canal for Irrigation and Navigation connecting the Damoodah and Hooghly Rivers,—(the 22nd August 1868.)

In accordance with the instructions contained in Joint Secretary's No. 240I. of 24th October 1867, I have the honor to submit a project with estimates for a canal from the Damoodah to the Hooghly.

2. Accompanying the project are the following plans and drawings:—

1 Book containing plans and sections of the line.

1 Roll of Drawings,—

Drawing No. 1, Weir across the Damoodah.

„ No. 2, Shutters for Under Sluices.

„ No. 3, Head Sluices.

„ No. 4, Entrance Lock.

„ No. 5, Syphon Culverts 3m. 3f.

„ No. 6, Aqueduct over Singarun.

„ No. 7, Canal Weir and Lock.

„ No. 8, Tumlah Aqueduct.

„ No. 9, Road Bridge.

„ No. 10, Aqueduct over Bankakhall.

„ No. 11, Double Flight Lock.

„ No. 12, Syphon Culverts.

The staff employed on the work have been Messrs. Whitfield and Unwin, c. e., Mr. Kriens, Mr. Nicholson, Baboos Gopaul Chunder Paul and Ausootosh Singh.

3. The first 24 miles were surveyed and levelled by Mr. Nicholson ; from 24th to 50th mile by Mr. Whitfield and Baboo Ausootosh Singh ; from 50th to 72nd by Mr. Unwin and Baboo Gopaul Chunder Paul ; and from 71st to the end by Mr. Whitfield, Mr. Kriens, and Baboo Ausootosh Singh.

4. Messrs. Whitfield and Unwin only arrived from England in April ; they went out into tents at once and worked most zealously and efficiently till 15th of June ; they were therefore working in the hottest and, during a portion of the time, the wettest season in the year ; most, too, of the decorative part of the book of plans is due to the exertions of Mr. Whitfield.

SECTION I.

Introductory.—The Government of India ruled in their Circular No. 111 of 5th November 1867 that certain data should be collected in the districts in which an irrigation project was proposed while the engineering surveys were being undertaken,

and suggested certain questions, particulars of which might be usefully obtained. Before, therefore, describing the proposed canal, I will endeavour to answer these questions *seriatim*. The information has been obtained from the Collectors of Hooghly and Burdwan, certain Zemindars, and my own personal observation. On the whole it is not, I think, satisfactory, and inclines more to opinions than facts; but to obtain reliable information on the points suggested, one or more Officers should be specially deputed to examine the whole District during the cold weather, to measure the land under cultivation, note the mode in which irrigation is practised, the quantity of water given at each flooding, the labor of giving it, &c., &c.: this would enable us to calculate with tolerable accuracy the cost of irrigation per acre, but I fear the result or advantages of the irrigation could never be obtained, certainly not from ryots, who view with extreme suspicion any enquiry into their profits, and invariably under-rate them.

Such an enquiry as this would probably occupy the entire time of two or three Engineers for the whole time that the crops were on the ground.

I will arrange the questions and answers in juxta-position.

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| <p>1. The rainfall from actual observations, with its distribution through the months of the year?</p> | <p>1. In Appendix A. are Tables shewing the rainfall in Burdwan and Calcutta in each month from the year 1859 to 1867 inclusive.</p> |
| <p>2. The depth of water below the surface?</p> | <p>2. Water is met with in Ra-neegunge and for 10 or 12 miles to east, at about 12 to 25 feet below the surface; from that point to Calcutta at about 10 to 12 feet.</p> |
| <p>3. Whether irrigation is now practised, and to what extent, actual areas being stated?</p> | <p>3. With regard to the extent to which irrigation is practised, the Collector of Burdwan. states that "no special means of irrigation are provided in this District; in drought irrigation to a limited extent is practised by leading the</p> |

water of tanks to a considerable distance where requisite: generally speaking, irrigation is not much wanted."

The Collector of Hooghly states "irrigation is carried on throughout the District generally and all along the course of the Kana and Sursuttee Rivers: the mode does not differ from that in other parts of Bengal. The water is first raised from the tank into small reservoirs, from which again it is conducted by small surface canals as far as the water will flow: this, however, seldom extends more than 100 yards from the tank or river side." The Collector, although unable to state the area of the land irrigated, believes it to be nearly equal to the area of the District, which is said to be 4,500 square miles.

I must say that I do not agree with the Collector of Burdwan in his remark that, generally speaking, irrigation is not much wanted in that District: my own experience leads me to the opinion that all the available water is used for irrigation, and the want of water is the only limit to general irrigation throughout the District. Between the point where the canal starts and Burdwan there is not a mile along the line in which irrigation of some kind is not resorted

to under great difficulties, and with but a small quantity of water : the small streams are dammed, and the water lifted from them by sewnies or baskets about 8 or 10 feet. Near Rancegunge the water is lifted from wells, where the surface of water is often 15 or 18 feet below the surface : nearly all the tanks are made use of. It is very much the same in the Hooghly District ; near all the villages irrigated crops are found ; and travelling down from Burdwan to Calcutta I saw rice crops being irrigated on the 23rd June this year, notwithstanding the heavy rainfall from 7th to the 19th of the same month. Mr. Herschell, the Commissioner, who was in the train, saw this also.

In the spring of the present year I was struck with the very great increase of rubbee crops in the neighbourhood of Pundooah, Mymarce, and Boinchee over what I had seen at the same places in 1863-64. I must say that refusing to believe that the agriculturists of this part of Bengal would not use water for irrigation, (when we see all the available water being used), if they could obtain it at a reasonable price, seems very much like the opinion expressed by men of great experience in India before Railways were constructed, that natives would not travel by them ; and to delay

making a canal, because the area irrigated now is small, is like the argument which has often been brought forward for not making a road, *viz.*, that there is no traffic. With regard to cost of irrigation, I calculate roughly that an acre of rubber crops now irrigated costs the ryots from 6 to 8 Rupees at least during the season, and this does not include the sinking of wells or making channels from tanks, or the implements used, and even then the crops are but indifferently watered.

4. The character of the agricultural seasons, whether the division of khurreef and rubber is maintained or not?

4. The agricultural seasons are divided into the rice and rubber; the former is cultivated from June till about the end of November, the rubber crops from November till March.

5. The more important crops of the districts, giving approximate areas of cultivation?

5. The principal crops of the District are Aus and Aman rice, sugar-cane, potatoes, chillies, cullai, gram, til, pân or betel, jute, pulses, vegetables of all kinds and mulberry.

The area cultivated in the Burdwan District is as follows :—

	Acres.	
Aus rice	40,000
Aman	6,10,000
Other crops used for		
food	38,000
Crops not used for		
food	16,500
Total	7,04,500

In the Hooghly District the area may be put down at 4,500 square miles, deducting $\frac{1}{2}$ for villages, tanks, &c., the area cultivated may be put down at 1,440,000 acres.

6. The weight of the ordinary produce of the unirrigated crops per acre for comparison with the produce of irrigated lands in the same or neighbouring Districts?

6. The Collector of Burdwan states that the produce of unirrigated crops is about 18 maunds of paddy per acre, and of irrigated crops 30 maunds paddy, where naturally irrigated every year by river overflow.

In Hooghly the Collector reports that ordinary produce of paddy is 15 or 18 maunds per acre: the produce of irrigated crops is not stated.

7. Whether there is at present any important export of agricultural produce; and, if so, to what places, and what are the chief staples?

7. There is considerable export of agricultural produce to Chander-nagore, Biddabatty and Calcutta of rice, sugar-cane and potatoes, but no particulars are obtainable.

8. What are the chief marts for the agricultural produce of the District, and what are the chief lines on which water-carriage is likely to be most valuable for purposes of inland trade, either in respect to agricultural produce or any other commodity?

8. The chief marts in the Burdwan District are Culna, Cutwa, Burdwan, Mancoor, Dignugger, Gooskarrah, Bhedia, Jamalpore and Chuckdiggee, and, in the Hooghly District, Hooghly and Biddabatty.

In the Burdwan District the Collector of Burdwan suggests that the only line proposed by the large Zemindars of the District is one starting from the Ramghur

Jungle Mehals, passing through the centre of the District in a south-east direction and falling into the Hooghly a few miles below Culna.

I take the Ramghur Jungle Mehals to mean the Hazareebaugh District ; the proposed line therefore would involve a canal about 250 miles in length ; it would cross many of the affluents of the Damoodah, among them the Burrakur, which discharges about two-thirds of what the Damoodah itself does, and the Burrakur water would be lost without very expensive works were resorted to for letting it into the canal.

I think these reasons alone,—to say nothing of its being far away from the principal collieries,—are sufficient to deter any consideration of this line for the present at any rate.

The Collector of Hooghly suggests two lines,—

1st,—From Chunderkona to Calcutte *viâ* Ghatal.

2nd,—Sreekristopore to Mugra.

The former of these lines would be better made from the Selye as far as Ghatal : from Ghatal water communication now exists throughout the year. The latter line is only a short one, and would be of no use whatever for the conveyance

of minerals: the line now projected will run about midway between these two places, and branches could be carried to both places if required.

9. What will be the probable fair money value of water to the chief crops likely to require it?

9. The Collector of Burdwan suggests Rupees 2 per acre on the average, and the Collector of Hooghly from 4 annas to 2 Rupees. I think myself that Rupees 3 per acre for the spring crops and 8 annas for the rice crops should be at first charged, subject to increase hereafter.

10. Whether the settlement of Land Revenue is permanently fixed or not?

10. The settlement of Land Revenue is permanently fixed throughout the District through which the canal passes.

11. Whether the Landholders will be likely to co-operate with the Government in the extension of irrigation?

11. All the principal Zemindars say they would second the aims of Government in inducing the cultivators to take the water.

This should be ascertained from actual enquiry of the chief of them.

For my own part I do not think much inducement is required, as the cultivators throughout the District are alive to the advantages of irrigation, and would, I think, at once avail themselves of it, provided the cost is not excessive, and the distribution given when required, and without any trouble to the people taking it.

12. Whether any special arrangements are suggested in relation to the system of charging for

12. The Collector of Burdwan says that no special arrangement is necessary; the Collector of

the water supplied consequent on any peculiarity of the tenure of land or otherwise?

Hooghly thinks that the Zemindars should be charged in a lump sum, as collecting it from the cultivators would entail more trouble and expense than collections would be worth.

I agree with the Collector of Hooghly in thinking that his plan would involve less trouble, but it has many objections. In the first place, judging from the relations that have hitherto existed between landlord and tenant in Bengal, it is not impossible that the rent enhanced by Zemindars on account of water would be really more than the amount paid by the Zemindars to Government, and the royts might thus be driven to refuse to take water. If it could be possible, it would, I think, be better to arrange the land to be irrigated into areas, either by villages or some other means, and give the cultivators of that area the means of taking what water they like at any time for a certain annual rent: this arrangement, however, could only be made with regard to the irrigation for the rice crop. For the rubbee, it would, I think, be better to flood a certain area for a certain sum.

13. Whether any protection by drainage, or embankment, or otherwise, is at the same time needed for the District, or parts of it?

13. Embankments will be needed at the head works and for the first two or three miles; after that the river bank is generally above

the highest flood; where it is not so, river embankments have already been provided.

Syphon culverts will be liberally provided to pass the drainage from one side of canal to the other, and towards the lower end of the canal drains will be cut parallel to the canal, to be turned into some of the existing drainage khalls.

SECTION II.

Situation of Head Works.—As one of the objects of the proposed canal is to establish a line of water communication between the Ranceegunge Coal-fields and Calcutta, the site for the head works is to a great extent restricted to the vicinity of Ranceegunge: fortunately, however, the river is more suitable here for the construction of a weir than almost in any other part.

About seven miles above Ranceegunge there is another site, which at first might have appeared to be more favorable, inasmuch as a trap dyke runs right across the river, which might to a great extent be utilized in the formation of a weir; it has the disadvantage, however, of cutting the stream at a small angle, this would not so much matter to the canal on this side, but the acute angle which the weir would make with the bank would cause a great silting in front of the head of a canal taking off from the right bank: this, however, might be obviated by building the weir at right angles to the stream from the point where the dyke leaves the left bank, and making use of the dyke, to form the down stream portion of weir. The first seven miles of a canal taking off from this point on the left bank would run over very undulating and rocky country; the excavation therefore would be very expensive, and the canal would require to be passed over the Nooniah Nuddee by an aqueduct. The advantages of having these seven miles of canal would be very slight, either for irrigation or navigation, and the great extra expense would completely neutralize the advantages

derived from having a portion of the weir already constructed and stone close to hand for the construction of the remainder.

The site ultimately selected for the weir across the river is in the village of Rogonathchuck, a little below the point where the Raneegunge and Bancoorah Road crosses: this point has been selected for several reasons. In the first place, the river above the site is straighter for two miles than it is in almost any other part of its course; the fall, too, is only 2 to $2\frac{1}{2}$ feet per mile; the left bank is specially favorable for the take-off of a canal; it is comparatively low, and the soil is alluvial, and no deep or difficult cutting is therefore involved. The right bank is not quite so favorable, as the banks are higher and harder, and the first portion of the canal would have to pass through a densely populated village. A canal, however, on the right bank has not been considered in this project, as a second canal from the Damoodah would not be possible until the dry weather supply of the river could be largely augmented by Reservoirs. Again, the head of the canal is contiguous to some of the principal collieries of the most important Coal Companies.

For the head works very good laterite is obtainable at Munglepore, on the Grand Trunk Road, about two or three miles from site: this will have to be brought down on a tramway; a hard gneiss is also procurable at Medjia, a small hill on the right bank, about a mile below the site of the weir: this would be difficult to work, although it would be capital material for the rubble portion of the weir. Still as the laterite is more easily worked, and is as good as any stone to resist the action of water, it may possibly be cheaper to bring all the stone required for the weir from Munglepore.

The present Raneegunge and Bancoorah Road will be diverted as shewn on Sheets Nos. 2 and 3, and raised so as to form a protective embankment for the head works and workshops, &c. The road will then impinge on the bank opposite to where the new road on opposite bank impinges, so that the ferry crossing will actually be more convenient; but the road will be continued along bank of river by a bridge over the fore bay of lock to head sluices, and eventually by a bridge over the weir, if such should ever be considered necessary.

Sufficient land will be taken up at site of head works for the brick-fields, workshops, &c., &c.

SECTION III.

General Plan of Canal.—The canal is designed for irrigation and navigation. When running full, it will carry 1,500 cubic feet per second, or sufficient to irrigate 200,000 acres of rice crop at the rate of one cubic yard of water per hour per acre.

From Appendix B. of heights on the Raneegunge gauge, it will be seen that from the 1st June to 15th November we may always depend on obtaining sufficient water from the river for this amount. There is one year in which the Raneegunge gauge reports (on which this Table is founded, compared with the actual discharge as measured by me this year) show a much less discharge by the river, but it was the first year in which the gauge was kept, and I am inclined to think there is some error in the reading. We may, I think, depend on being always able to irrigate the rice crop to the full amount the canal can carry.

From the 15th November to the 15th March we may, without any supplement from reservoirs, reckon on 200 cubic feet per second, or on being able to irrigate 64,000 acres, allowing that one cubic foot per second is sufficient for 320 acres of spring crops. After the 15th March the canal will be turned into a still water one for navigation; the quantity coming down the river being reserved to supply the waste by evaporation and lockage. Supposing that $\frac{1}{2}$ inch of surface per diem is lost by evaporation throughout the length of the canal from 1st March till 1st July, the whole amount lost will be 76 inches, and the quantity required to supply the loss will be 26 cubic feet per second.

Supposing, too, that 50 boats pass through the canal daily, the loss by lockage to be re-placed by the river will be 14 cubic feet per second, or 40 cubic feet per second required altogether when the canal is still: there are but very few days in the year when this could not be obtained from the river; when a fresh occurs in the river from rain falling on some portion of the basin, a flooding could be provided: these freshes are by no means unfrequent during April and May. The canal when carrying the full supply will be 114 feet wide at the surface, 7 feet deep, and side slopes of 2 to 1: it will have a fall of 6 inches per mile. According to Eytelwein's formula $V = 9\sqrt{2f \times d}$ where f is fall per mile in feet and d the hydraulic mean depth; the canal at this section will carry about 1,500 cubic feet.

The fall will remain 6 inches per mile up to the 28th mile. From that point the fall will be reduced to 4 inches, the section remaining the same; the discharge therefore will be 1,260 cubic feet per second. At the 35th mile the fall will be reduced to 3 inches, and the discharge from that point will be 1,092 cubic feet per second.

At the 49th mile the section will be reduced to 90 feet surface width and fall of 4 inches per mile: the discharge by this section will be 900 cubic feet per second. The reason I have determined to reduce the section here is to pass through the town of Burdwan, taking up as little land as possible, as the land in the town will probably be expensive from the number of houses, &c., that will have to be removed.

At the 60th mile the fall will be again reduced to 3 inches per mile, and from the 71st mile the bed will be horizontal, or only have enough fall to carry the water forward.

The canal runs up to the 49th mile on the ridge line, and the area commanded by it throughout is very much more than we should have water to irrigate; while the section, therefore, has been kept uniform for conveniences of navigation, there is also the advantage of being able to take the water into the lower reaches, in the event of its finding a more ready sale there than in the higher reaches.

Throughout the canal arrangements will be made for stop-boards at each fall to keep back the water level, and 5 feet deep on the sill of upper lock whenever the discharge would give a less depth than 5 feet.

In cuttings, the towing-paths will be 3 feet above surface of water and 9 feet broad. Where the canal runs between embankments, the crest will be the towing-path; it will be 10 feet broad and 3 feet above water level.

I have marked on Sheet No. 1 the general direction of the distributaries and the area each will irrigate up to the full amount the canal can carry: this area is not half what is actually commanded by the canal.

When the canal is carrying the full supply, the velocity will be 2·2 feet per second; with the full section and fall reduced to 4 inches the velocity will be 1·8 feet per second, and when the fall is 3 inches the velocity will be 1·5 feet per second.

In the reduced section, when the fall is 4 inches, the velocity will be 1·7, and when 3 inches, 766 cubic feet per second.

SECTION IV.

Plan of Head Works.—The general arrangement of the head works is exhibited in Sheet No. 3, with a section of the river in the line of the weir.

The weir will be 3,000 feet long and 10 feet above the dry weather level of the river. From several sections of the river the maximum calculated discharge is 3 to 400,000 cubic feet per second: this is less than what has generally supposed to have been the maximum discharge of the Damoodah; but from a longitudinal section and several cross sections taken in the straight reach of the river two miles above the weir, the discharge calculated according to Eytelwein's formula is a little over 300,000 cubic feet per second. Assuming the discharge to be 400,000 cubic feet per second, the afflux in high flood will be 1·5 feet.

The weir will be at right angles to the river; it will be 3,000 feet long and 10 feet high. The dry weather stream is 240·64 above mean sea level, and crest of weir will be 250·64. The highest known flood observed on a gauge some little distance higher up is 260·64.

The weir will be provided on each side with six under-sluices of 50 feet span each: the flooring of these will be at 240·64: the vents between piers of under-sluices will be closed by gates on the French pattern, to be described hereafter. The main portion of the weir consists of three lines of wells, 6 feet diameter, sunk across the stream to a depth of 6 feet. On these will be built a wall up to crest of weir on inner line; the walls on outer lines will be up to height of exterior slope of weir, which is 12 to 1. Between the outer walls boulders will be thrown in, the upper layer being packed, and the first 22 feet from crest of weir will be laid horizontal, and will consist of cut laterite set in lime cement. On the up-stream side of the weir boulders will also be thrown in to a width of 20 feet; the stones at surface being packed to a slope of 2 to 1.

The whole of the wells will be of one ring of 9-inch bricks, the interior being filled in with concrete composed of small laterite and ghooting lime. The foundations of under-sluices will consist of four walls built on 6 feet wells; between the outer walls the sand will be excavated

and stones laid to a depth of 4 feet. Between ~~the~~ inner and third wall sand will be excavated in a similar way, and stones placed in the lower 2 feet 9 inches: the upper 1·25 will consist of cut laterite set in lime cement. The foundations of piers will be on 6 feet wells; they will be 10 feet high, and will also be of cut laterite set in lime cement.

Between the under-sluices and main portion of weir will be flank walls to keep the stones of weir from moving.

On both banks there will be curved wing walls built into the river bank.

The head sluices for the supply of the canal will be 15 in number, and consist of 5 feet vents each: these will discharge, with a head of 4 inches, 1,500 cubic feet per second. The embankment round the head works and the roadway over entrance lock and head sluices will be 263·64 above mean sea level, or 3 feet above highest known flood. The floor of head sluices will be at 243·64.

The gates of under-sluices in the weir will consist of two rows of gates in pieces of 10 feet long, working on a centre pivot and lying flat and outwards from each other during passage of flood: the up-stream gate will be only 6 feet high, and will be kept down by a button. At the time of closing the gates the button will be released, and the gates will be moved in to a vertical position by the water and be held there by two chains. The water being thus held back, men would go in and lift up the outer gates: these would be 10 feet high and are held up by iron bars, which slide in a groove, the bars being shifted laterally into a notch when vertical: these larger gates are shod at the edges with iron to make them water-tight. As soon as the large gates are in position, the smaller gates may be let down and fastened. The larger gates are let down by a rod moving horizontally, to which a projecting tooth is attached, which moves the rods out of the notch, and they then fall. The Drawing, No. 2, explains the working of the gates.

The entrance lock is 1,000 feet above the weir: both sills of the lock will be at the same level, *viz.*, 243·64, that of the bed of the canal; there will be a bridge over the fore bay of the lock.

The lock will be filled and emptied by valves in the bottom of the gates the whole width of the gates and 1·25 feet deep: these are on a

pattern which has been, I believe, successfully used on the Kendraparah Canal in Orissa.

The weir, head sluices and entrance lock will be entirely constructed of laterite.

SECTION V.

Alignment of Canal.—From the head works the line of canal for the first seven miles of its course runs close to the river.

The ground rises rapidly from the river to the Railway, which is about one or two miles distant and parallel to the river. Two small drainage khalls are met with at $1\frac{1}{2}$ and $3\frac{1}{2}$ miles; the former runs from a large swamp just south of the Railway, and a great portion of the water it drains is what enters the swamp from the river when the latter is in flood. The other drains about two or three square miles, and I propose to pass both of them under the canal by means of a syphon culvert, as shewn in Drawing No. 5: these four spans of 6×5 , with a head of 6 inches, will pass 420 cubic feet of water per second. At $7\frac{1}{4}$ mile the Singarun River is met with. As the land here is very sandy near the river, I propose to cross the Singarun as close to the Railway Bridge as possible, cutting a new channel for the river as shewn by the red dotted lines.

I propose taking the canal over this channel in an aqueduct of nine arches of 50 feet span each. From the longitudinal and cross sections I have had taken, I make the maximum discharge of the Singarun to be 28,846 cubic feet per second. The nine 50 feet arches will give an area of waterway of 4,134, which will be ample for the greatest possible discharge of the stream. I think myself the discharge of the Singarun is over-estimated, and that the high flood lines marked on the Railway and Grand Trunk Road Bridges are due to the back-water of the Damoodah rather than to the flood of Singarun; however, as in the event of diminishing the waterway we should have to provide gates to keep out the Damoodah flood back-water, I have preferred to follow the examples of Railway and Grand Trunk Road, and allowed sufficient waterway for the ingress of the back-water.

The Railway Bridge over the Singarun consists of 14×12 feet arches and three 80 feet girders, giving an area of waterway of 4,080 feet, supposing flood level as estimated by the Railway Authorities is correct.

The Grand Trunk Road Bridge is on the suspension principle, with centre span of 150 feet and two side spans of 66·5 each : this gives the waterway 3,996.

The canal is carried between embankments for a mile before reaching the Singarun. The Singarun Aqueduct will be built of rubble stone brought from the Tumlah Hill, and the arches will be of brick ; the design is shewn in Drawing No. 6.

From the Singarun the canal will run nearly parallel to and about $\frac{3}{4}$ to $\frac{1}{4}$ mile distant from the river, until it arrives at the Tumlah, which is met at 13 miles 5 furlongs. From the Singarun to the Tumlah no obstacles are met with, but the country is much broken, and some heavy cuttings are necessary. At the Tumlah a low spur of the high land south of Adjai runs down to the river, and the Tumlah runs round it to the south, before entering the Damoodah : fortunately there is sufficient room between this hill and the river to carry the canal ; had it been necessary to cross the hill, we should have had a mile of very deep rock-cutting. From this hill we shall be able to obtain very good stone for the sills, quoins and copings of the locks.

The Tumlah is a small stream, whose discharge, from calculations, I make to be 12 to 14,000 cubic feet per second.

The Railway Bridge over the Tumlah consists of 17·20 feet arches, and from the flood line marked on the section the waterway in greatest flood is 2,160.

The Grand Trunk Road Bridge is on the suspension principle, the centre span is 85, and the two side spans 24 feet each : the area of waterway according to flood line marked is 1,537 square feet. I propose taking the canal across in an aqueduct, consisting of nineteen 20 feet arches, and through this the small stream which runs to the east of Tumlah Hill will also pass. The area of waterway allowed is 2,186, which will, I think, be ample for the greatest floods. We shall also be independent of any arrangement in the way of shutters to keep the Damoodah back-water out.

The design of Tumlah Aqueduct is exhibited in Drawing No. 8. The arches will be of brick ; all the rest rubble stone, which is obtainable at site.

From the Tumláh the canal will turn northwards again towards the the Railway, so that the deep valley between 18th and 19th mile, which runs from the Railway down to the river, may be crossed in its highest point, and also we may be able to reach the ridge line beyond the valley. The embankments in this valley will be heavy, averaging about 23 feet in height; but if we keep lower down and look before we come to the valley, we shall still have heavy embankments, and the country beyond is very broken and undulating, and it would be some miles before we should again come out on the ridge line; I think therefore that the line selected is the best, as, after crossing the valley, we run on the ridge line and on comparatively level ground; there is very little drainage water passing through the valley I have just mentioned, and a syphon culvert of four vents, such as I have provided at 3 miles 3 furlongs, and as shewn in Drawing No. 5 will be ample; the canal having crossed the valley will run parallel to Grand Trunk Road and Railway. At 24 miles 4 furlongs the canal crosses the Paneeghur and Sonamooky Road: this will be taken over the canal by a bridge, as shewn in Drawing No. 9. It may be advisable for economy's sake to alter the position of Lock No. 5 and place it so that the road bridge and lock may both be at the same site.

From Paneeghur and Sonamooky Road the canal will run on the ridge line and parallel to the Grand Trunk Road, which is here south of the Railway, having been crossed by it just beyond Paneeghur Station, and no difficulties or obstacles are encountered till between the 38th and 39th miles. Here there is a very large village called Golegram, which extends up to the Grand Trunk Road. If we go to the south of the village we fall upon the Kandur Khall, which rises a little west of Golegram; the canal therefore will be taken through the village: for similar reasons it will be taken through the village of Gulsee, another large village, which occurs just beyond the 41st mile. The ground has a general fall of about 4 feet per mile: from the 24th mile eastwards many locks are therefore required. At 35 miles the lock will be in two flights, as shewn in Drawing No. 11. At the 49th mile the surface width of canal will be altered to 90 feet, and the canal will take a southeasterly course towards the south part of the town of Burdwan. At 52 miles 4 furlongs the Banka Nullah occurs: this is a small stream, which rises about 18 miles west of Burdwan. By calculations I make the

maximum discharge to be 4929·8 cubic feet per^s second, and for this I have allowed a waterway of 1,016, which, I think, will be ample. The Grand Trunk Road Bridge over this nullah consists of 2—22 feet, 2—24 feet, and 1—32 feet arches; with the flood line shewn the area of waterway is 1,652. The Railway Bridge consists of 4—80 feet spans, and according to water line shewn on plan the area of waterway is 2,942 feet. Both the Railway and Grand Trunk Road Bridges were built before the country on the left side of Damoodah was safe from the Damoodah floods; at a time when breaches in the embankment were of yearly occurrence, and a certain portion of the Damoodah water passed down the Banka Nullah; the bridges therefore must have been designed more to be able to carry off this supplement from the Damoodah than for the waters of the Banka alone: this, too, is evident from the viaduct, about $\frac{3}{4}$ mile long on the Railway just east of Burdwan. Since, however, the embankments on the right bank of Damoodah have been removed, and those on the left bank have been made and maintained in their present fine order no water whatever passes from the Damoodah through the Banka, and all it has to discharge is the rainfall on its own basin: this, before crossed by the canal, is not more than 70 miles or 80 square miles. Under these considerations, therefore, I think the waterway I have allowed will be ample. The aqueduct will be built of brick according to design shewn in Drawing No. 10. After the Banka the canal will run through the southern portion of the town of Burdwan, the suburbs as it were: a considerable number of houses will have to be moved, and some five or six metalled roads will be crossed: these can be arranged so that three bridges over the canal will be sufficient for the traffic.

Had the line been continued to the north of the town of Burdwan, it would have necessitated the destruction of more valuable house property and the crossing of the Grand Trunk Road and two or three others. I have arranged for the road crossings through Burdwan three similar bridges to the one shewn in Drawing No. 9.

Passing through the town of Burdwan the canal runs about $\frac{1}{4}$ mile from the Damoodah Embankment. At 62 miles 1 furlong the head of the Gungoor Nuddee is crossed: this rises close to the canal, so that a small syphon culvert will be ample for the drainage. There is nothing worthy of notice in the line up to the 69th mile, where the canal crosses

the Mymaree and Jamālpore metalled road: this will be taken over the canal by a bridge similar to that in Drawing No. 9.

From 71st mile the canal will be still, the bed only having sufficient slope to carry the water forward.

At 78th mile there will be another road bridge, similar to the others, to take the metalled road to Boinchee over the canal, and another also at 82 miles 4 furlongs for the Mugrah Road; another at 84 miles 4 furlongs, and another at 89 miles 5 furlongs for the Hooghly Road.

From 71st to 88th mile no extraordinary works will be required.

At 85 miles the lock will be in two flights. Between the 88th and 92nd miles some embankments that now exist will have to be cut through: these embankments are high and seem from their position to have been made for the protection of individual villages at a time when the Hooghly District was annually flooded to a certain extent by the Damoodah. At the 92nd mile the Kadarmutty is met with: this is a branch of the Koontee, and discharges but a very small quantity of water. I propose to go through it, and divert it by a channel running north of, and parallel to canal, to join the Koontee, using the earth from the new channel for the canal embankments.

The Koontee is met with at 93 miles 6 furlongs: it is what is some times called the Kana Damoodah; it was formerly connected with the Damoodah at Jamālpore, and a portion of the Damoodah waters passed by it into the Hooghly at Noaserai: it intersected the road from Mymaree to Jamālpore, and an expensive bridge had been sanctioned for construction over it. I found in 1863, by comparing its discharge with that of the Damoodah, when the latter was in flood, that it had silted up so much as to be useless as an aid for the drainage of the surplus waters of the Damoodah. To avoid, therefore, the expense of the bridge about to be constructed over it, I recommended its being closed by a dam, which was sanctioned and constructed in the same year. I may add that I first wrote to all the Zemindars regarding the closing of the channel, and they were all in favor of it. Since 1863, therefore, no water has passed by the Koontee from Damoodah; I think therefore that a syphon culvert, as shewn in Drawing No. 5, will be ample to pass the drainage.

At 94 miles 4 furlongs the canal will meet the Sursuttee : this is a small drainage channel, which appears to run parallel to the Hooghly, joining both at Tribanee Ghât near Mugrah and at Sankrail below Calcutta ; it is embanked across in many places, I presume, for irrigation ; it drains therefore little or no water, and Mr. Whitfield, c. e., who was out surveying here during the severe rains from the commencement to middle of June, says that there was never more than 2 or 3 feet of water in it at that time ; I therefore propose to pass its waters by a syphon culvert similar to that provided for the Koontee and as shewn in Drawing No. 5.

Although it is, perhaps, out of place to bring it forward here, I cannot help thinking that if the Sursuttee and Koontee Nuddee were looked at as drainage channels, and if the embankments about the District were removed or cut across here and there, that fewer complaints would be heard regarding the epidemic that has prevailed for some years in the Hooghly District. The embankments were made when there used to be large quantities of water going over the country. The necessity for them now does not exist. Dams, too, appear to be made in these nullahs without any regard to arrangements for drainage ; however, any propositions or projects would be useless, unless legislation could enforce their being carried out. I may also mention here that a map of the Hooghly District is very much wanted ; the only one obtainable is the 4-mile to inch map, as the Revenue Survey Maps have been condemned, and the Survey Department refuse to issue them : a map on the scale of one mile = 1 inch would have been of great value in the survey of this canal, if it only shewed the villages, streams, &c. ; and the Revenue Survey Maps must have been bad indeed, if they did not arrive at this standard of excellence.

From the Sursuttee Nullah the canal will run through and skirt some large villages, especially Bigatty, which occurs at 97th mile, and, going through the thinnest part of the Biddabatty, will enter the khall of that name about 1,500 feet above its junction with the Hooghly ; the lower sill of the lock being 3 feet 6 inches below low water level neap tides, so that boats will be able to pass in and out of the canal at all times. At 99 miles 7 furlongs the Grand Tunk Road is crossed at the point where it is intersected by a local metalled road : these will be joined before reaching the canal and taken over by one bridge similiar

to *Drawing No. 9*: the arrangement is fully illustrated in the general plan of terminal works. The whole length of the canal is 100 miles $2\frac{1}{2}$ furlongs.

I have arranged for 60 small syphon culverts, as shewn in *Drawing No. 12*, to be distributed along the line: these, with channels cut parallel to canal to join the natural khalls where convenient, will be sufficient, I think, to pass the drainage from one side of the canal to the other.

SECTION VI.

Terminal Works.—The Biddabatty Khall from the point where canal enters it to the junction with Hooghly will be cut with the same width at bottom as canal and slopes of 2 to 1.

The bridge by which the Railway crosses the khall will have to be altered; it consists at present of 6 spans of 12 feet each. I propose therefore knocking down the 1st, 3rd and 5th piers, and building up the 2nd and 4th, and substituting 36 feet girders in lieu of the arches. The rail level will remain the same, as, from bed of girder to high water level spring tide, there is 5 feet of headway.

The road bridge will not be altered: it is 20 feet wide in the clear, and from level of girder bed to high water spring tides is 8 feet. All the distributaries will terminate in the natural drainage channels of the country.

SECTION VII.

Rates and cost of works.—In the abstract of the estimate is exhibited the cost of each item of the works and the total cost, which is Rupees 45,24,816.

The cost of land is entered at Rupees 4,01,600. I have arrived at this in the following way:—For the first 49 miles of the canal I estimate that we should require on an average a strip 300 feet in width, which is 110 beegahs, or $36\frac{2}{3}$ acres per mile. Allowing .40 acres, (the extra quantity being required for head works, sites of bungalows, &c., &c.), and assuming the rate per acre as Rupees 120, the cost of land for first 49 miles = Rupees 2,35,200. For the remainder of canal I estimate that we should require a width of 200 feet: this gives 73.3 beegahs, or

24.4 acres. Allowing, therefore, 27 acres per mile, and the price as before, Rupees 120 per acre, the cost of the last 52 miles will be Rupees 1,66,400, making whole cost of land Rupees 4,01,600. Much of this land may be re-sold or let for gardens and plantations as soon as the works are completed, or even if retained by Government and planted with trees the produce will give a very fair interest on the whole outlay. With regard to the dirtributaries, I have simply estimated them at Rupees 2 per acre commanded.

The rates for earth-work, brick-work, &c., have been fixed as follows:—I have obtained the rates now prevailing on the Railway, the Chord Line, East India Irrigation Company's Canal at Midnapore and the Public Works Divisions of Grand Trunk Road and Damoodah, and from these I have made out a list giving a very liberal margin to cover any rise in prices or any unforeseen difficulties in the work. The cost of locks and falls have been calculated at so much per foot of lift, and the rate of the foot of lift has been obtained from Estimates Nos. 6 and 10. In the former the cost of the fall and Lock-keeper's house, &c., is estimated, and the latter the lock. For altering the Railway Bridge at Biddabatty, I have entered the probable cost in a lump sum at Rupees 1,00,000.

I have made no allowance for accommodation for subordinates, as a two-roomed building has been estimated for at each of the locks.

SECTION VIII.

Income, expenditure, and profits.—As I have before stated, the canal will be capable of irrigating thoroughly 200,000 acres of rice crop and 64,000 acres of rubbee crops without any supplement from Reservoirs.

It is not always that the rice crop requires irrigation, although, no doubt, it would be very much improved by a more liberal supply of water; but generally in each year there is a slight drought, during

which the crop suffers to a certain extent, and at this time the cultivators would, I think, gladly purchase water; but, as a rule, I do not think that the ryots would enter into any arrangement for the irrigation of the rice crop at the beginning of the season, but would prefer to run the chance of the rain being sufficient, until they actually found their crop suffering for want of water, when they would very gladly purchase it. However the Zemindars, if the arrangement for sale of water is made through them, might purchase it for the irrigation of the rice crop throughout the year, and the ryots themselves may discover the difference in the weight of produce from a regularly irrigated crop to one only irregularly watered by rain. Until, however, this happens, I think we should not reckon on obtaining more than 8 annas per acre from the rice crop, or altogether Rupees 1,00,000.

From the spring crop, 64,000 acres, we might fairly reckon on being able to obtain Rupees 3 per acre. I think myself this price is very low, and that for the sugar-cane crop on the upper part of the canal, and for the vegetables in the lower part for the supply of the Calcutta market, as well as for the sugar-cane and betel gardens, we should easily obtain twice or three times this price. I reckon that the cost of the labor alone, judging from present rates, as irrigation is now carried on, is not less than 5 or 6 Rupees per acre, and to this have to be added the making of tanks, wells, channels and implements for raising the water. The rubbee crop at Rupees 3 per acre would amount to Rupees 1,92,000, and the total income derived from irrigation would be Rupees 2,92,000. Deducting one-sixth for cost of collection, the profit from irrigation alone would be about Rupees 2,50,000.

Income derived from navigation.—The coal annually lifted by the principal mines, *viz.* those belonging to the Bengal and Beerbhoom Companies, and to Baboo Gobind Persad Pundit, are 170,000, 59,000 and 67,000 tons respectively. Of this amount about 46,000 tons are conveyed by river, but a very large quantity more would go were the route shorter and less dangerous.

The present cost of carriage for a ton of coal by Railway to Biddabatty is Rupees 4-8, the cost by River Moiraka is on an average

Rupees 3-8 per ton, and this does not include any allowance for loss by wrecks, which is admitted to be about 10 to 15 per cent.

Supposing that a toll of 2 pies per ton per mile is charged on the canal, and that the cost of carriage is 4 pies per ton per mile, (and this is much more than it is likely to be,) the cost of a ton of coal to Biddabatty would be Rupees 3-2-0 : this is a saving of Rupees 1-6-0 on cost by rail, and 6 annas by river. In addition to this, in the former case the disadvantage and expense of breaking freight at Biddabatty is saved by the canal, as the boats would at once go into the Hooghly, either to the purchaser or to the store. In the case of the river, the charge has only been reckoned to Moiraka, which is 24 miles from Calcutta, going through the East India Irrigation Company's Canal, and 50 by river ; the expense therefore would be materially increased by either route before the coal arrived as much below Calcutta as Biddabatty is above it.

I think we may easily reckon on carrying 100,000 tons ; when the Chord Line is open, and the Raneegunge Line, instead of being as it is now almost exclusively a coal line, becomes the quick traffic line, the Railway Company will, I should imagine, be very glad to be relieved of the carriage of a large portion of the coal traffic, and a much larger quantity will pass down the canal. However, estimating that 100,000 tons are conveyed, and charging toll at the rate of 2 pies per ton per mile, or Rupees 1-4-0 per ton passing through, the income derived from coal alone will be Rupees 1,25,000.

The other minerals that will find their way from Raneegunge to Calcutta are stone for building purposes, both from Burrakur and Susiniash, metal not only for the roads of Calcutta, but for almost all the roads of the Burdwan and Hooghly Districts. Then, again, there is the timber from the jungles of Pooroolia and Hazareebaugh, to say nothing of the small sāl which I saw this year going down from Panee-ghur in some quantities to Calcutta by rail. Allowing, therefore, Rupees 2,00,000 as the income derived from navigation, and this I

feel sure is under the mark, and Rupees 2,50,000 as that derived from irrigation, the net annual profits of the canal will be Rupees 4,50,000.

The cost of constructing the canal being Rupees 45,11,923, the annual income derivable from the canal will be 10 per cent : this percentage would be sufficient to recommend the work to private enterprise, more especially as, whilst I have allowed very liberal rates for the construction of the work, I have rather under-estimated the profits ; but the fact of being able to ensure the safety, under any circumstances, of 200,000 acres of the staple crop of the country when the calamities of Orissa, the result of drought, are fresh in the recollections of every one, and of also being able to put under cultivation 64,000 acres of land, which now lie uncultivated half the year for want of water, are I think far more sufficient reasons for the work being undertaken by Government than the mere percentage which the profits bear to the capital, especially too, as I have before endeavoured to show, when the inhabitants of the country are willing agriculturists, and even now spare no trouble in bringing under cultivation in the dry season any small area of land to which water, however small in quantity, can be brought.

SECTION IX.

Mode of carrying out the works.—The whole work will probably be completed in three full working seasons.

The way I would recommend the work to be carried out is this :—In the first year set out the line, take up the land and fix the sites of locks, &c., and confine construction to the head works and first 24 miles of canal, and to brick-making and collection of materials at sites of different works along remainder of line. In the second year I would continue the construction of first 24 miles, and the masonry works throughout, and heavy earth-work of remainder ; and in the third year work over the whole line to completion.

APPENDIX A. RAIN-FALL AT CALCUTTA.

DATE.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	REMARKS.
1859..	0.00	0.66	4.23	1.29	3.18	12.48	9.09	21.22	11.55	4.96	0.00	0.00	68.66	
1860..	0.00	0.09	0.00	2.47	2.21	6.46	17.92	14.65	7.13	1.68	0.00	0.00	52.61	
1861..	0.56	0.00	0.88	0.31	9.07	26.44	10.93	16.12	12.48	7.75	4.39	0.26	89.19	
1862..	1.03	0.00	1.69	2.53	3.80	13.63	13.31	12.03	10.86	14.40	0.00	0.20	73.48	
1863..	0.00	1.20	0.00	2.43	4.20	12.93	11.22	14.10	10.33	3.48	1.26	0.00	61.15	
1864..	0.00	0.47	1.84	1.11	10.36	18.73	13.09	16.64	12.59	6.50	2.89	0.00	84.22	
1865..	0.48	1.86	1.96	4.28	15.94	8.63	12.19	5.99	10.29	0.00	0.00	0.00	61.58	
1866..	1.91	3.74	0.00	1.81	2.56	7.02	13.42	11.48	15.97	7.83	0.00	0.00	65.74	
1867..	0.55	0.82	1.51	0.27	2.45	7.21	15.40	18.50	13.70	8.12	8.19	0.00	76.72	
1868..	0.05	0.18	0.16	5.47	5.80	26.60	11.17	24.83	15.51	1.53	...	...	...
Mean	0.458	0.902	1.227	2.197	5.957	14.013	12.774	15.556	12.041	5.625	1.858	0.501	70.372	

A

RAIN-FALL IN BURDWAN.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	REMARKS.
1859...	0.00	1.00	7.80	2.40	6.70	7.30	11.10	11.20	5.40	3.60	0.00	0.00	56.70	
1860...	0.00	0.20	1.20	4.00	2.80	11.80	12.20	11.80	11.30	3.60	2.00	0.00	60.90	
1861...	0.00	0.00	0.70	0.70	5.80	15.80	24.95	7.20	17.90	11.20	1.30	0.35	85.30	
1862...	0.20	0.00	0.70	0.50	4.40	8.95	18.65	5.85	7.75	12.65	0.00	0.00	62.65	
1863...	0.00	0.50	0.00	1.65	4.45	11.50	8.80	15.30	4.95	2.00	0.30	0.00	49.45	
1864...	0.00	1.20	0.70	0.70	5.90	6.15	14.25	10.20	4.80	0.80	0.50	0.00	44.40	
1865...	0.00	3.30	1.80	2.00	13.85	7.90	13.05	5.80	7.95	0.00	0.00	0.40	56.05	
1866...	1.75	6.65	0.60	2.70	2.10	13.85	14.80	12.80	6.20	2.30	0.00	0.00	63.65	
1867...	0.40	0.60	1.80	2.35	3.05	10.60	8.75	13.65	12.00	5.35	2.70	0.00	61.25	
1868...	...	0.07	0.09	1.9	6.5	8.20	10.80	29.60	14.50	1.00				
Mean..	0.235	1.352	1.539	1.89	5.555	10.225	13.735	12.34	9.275	4.24	0.755	0.083	60.088	

APPENDIX B.

Raneegunge Gauge readings and corresponding discharge by River.

	1860.		1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.	
	Raneegunge Gauge.	Discharge cubic feet per second.	Raneegunge Gauge.	Discharge cubic feet per second.	Raneegunge Gauge.	Discharge cubic feet per second.	Raneegunge Gauge.	Discharge cubic feet per second.	Raneegunge Gauge.	Discharge cubic feet per second.	Raneegunge Gauge.	Discharge cubic feet per second.	Raneegunge Gauge.	Discharge cubic feet per second.	Raneegunge Gauge.	Discharge cubic feet per second.	Raneegunge Gauge.	Discharge cubic feet per second.
January 3rd
January 15th
February 3rd
February 7th
March 16th
April 3rd
April 15th
May 1st...
May 15th
June 1st
June 15th
July 1st..
July 15th
August 1st
August 15th
September 1st
October 1st
October 15th
November 1st
November 15th
December 1st
December 15th

From the Government of Bengal, to the Government of India,—
(29th December 1868.)

In your letter No. 34*I*. dated 16th March 1867, instructions were conveyed to the effect that “ designs and estimates for head works and canals on both sides of the Damoodah, including one for navigation to connect Raneégunge with the Hooghly, should be put in hand as speedily as possible, the necessary surveys and sections being at once proceeded with.”

2. As soon as the services of a properly qualified Officer could be found, the above instructions were complied with, and Captain Garnault, R. E., was appointed to the special duty of designing a canal from the Damoodah to the Hooghly.

3. That Officer has now submitted, through the Superintending Engineer, South-Western Circle, a complete set of plans* and estimates,† which I am directed by the Hon^{ble} the Lieutenant-Governor to forward for the favorable consideration and sanction of His Excellency the Governor General in Council.

* No. 67 of 1868-69.

† „ 37 of „

4. Previous to the commencement of the investigations, the views of the Government of India and of the Secretary of State were communicated to the gentlemen who, in the year 1866, submitted a proposal for a similar project, and offered to carry it into execution under certain conditions. As no further action was taken in the matter by those gentlemen during the six months following that communication, and as the project was one necessarily combining irrigation with navigation, the Lieutenant-Governor determined to allow no further delay to occur, and directed the surveys to be proceeded with at once.

5. As the accompanying Note by the Chief Engineer for Irrigation fully reviews the professional details of the project, it is not necessary to give more than a brief general summary of it here.

6. The projected works consist of a weir 10 feet high across the Damoodah opposite to Raneégunge, and a canal taken off from its left flank, which, after passing through the Town of Burdwan, terminates at

present in the Biddabatty Khall, which enters the Hooghly at Serampore.

7. The canal, whose length is somewhat over 100 miles, is designed to serve the double purpose of irrigation and navigation, the locks being so arranged as, in the event of the necessity arising, to reduce the canal to still water, with a depth of 5 feet over the lock sills.

8. It is proposed to have a discharging capacity of 1,500 cubic feet per second, sufficient for the full irrigation of 200,000 acres of monsoon rice, or from the 1st of June to the 15th of November, during which time that quantity of water is available in the Damoodah. After that date, however, the volume of the river continues to diminish until the 15th March, but never falling to less than 200 feet per second during that interval, so that, if 1 cubic foot per second is sufficient for 320 acres of rubber cultivation, an area of 64,000 acres may be provided with irrigation during the cold weather without any aid being necessary from Reservoirs.

9. For the purposes of navigation, and to meet the waste of lockage and evaporation, a supply of 40 cubic feet per second is enough, and this may always be ensured.

10. To secure the above capacity with, at the same time, a moderate current, it is necessary to give the canal a width of 114 feet at the surface for 49 miles of its course ; for the remainder, the width is reduced to 90 feet.

11. As the traffic on this canal cannot but eventually be very considerable, and as one item will, no doubt, consist of rafts of timber and bamboos, it is desirable that the waterway should be large, and though at the outset it may be advisable to limit the width to 75 feet at the surface, both in order to reduce the cost and to secure a more rapid completion, yet there can be little doubt but that the full width, as designed, will prove eventually necessary, and therefore no reduction has been made in the estimate.

12. That estimate, as prepared by the Executive Engineer, is, in the Chief Engineer's opinion, unnecessarily high ; but as prices of materials and labor appear to be steadily rising, it is, perhaps, more prudent to

refrain from making any reduction. Certain items, however, have apparently been omitted in the Executive Engineer's estimate, and these it is necessary should be inserted. With these additions, the estimate, exclusive of any item for special superintendence, amounts to Rupees 50,24,816, according to the accompanying revised abstract, and for this sum the Lieutenant-Governor directs me to solicit sanction.

13. As regards the financial character of the project, and the prospect of its being ultimately remunerative, the Lieutenant-Governor has little doubt. The existing elements of trade are, as shown in the Chief Engineer's Note, already sufficient to yield a moderate income, while his analysis of the rain tables shows the necessity that exists for providing artificially against the uncertainty of the rainfall, especially in the month of October, as a failure during that, the last, month of the cultivating season imperils the out-turn of the whole crop in Lower Bengal.

14. The Lieutenant-Governor is disposed to concur in the Chief Engineer's view that, if the Executive Engineer's estimates are high, his calculation of the returns is low, and that those anticipated by the Chief Engineer are not more than may reasonably be expected.

15. The Lieutenant-Governor further concurs in the view that it would be impolitic not to make the fullest use that the canal will admit of for the irrigation of the cold weather crops, and would, therefore, strongly urge the construction of the Reservoirs in connection with this project as calculated to effect the two-fold purpose of saving that part of the country which is now periodically injured by the Damoodah floods, and securing a portion of that tract which is liable to suffer from the uncertainty, and oftentimes too early cessation, of the rains.

16. The Government of India, in letter No. 1727. dated the 4th November 1867, enjoined the collection of certain data in connection with all new projects for irrigation. These have been compiled as far as possible, and are for the most part satisfactorily explained in the Executive Engineer's report. The only points which seem to call for any particular notice by the Lieutenant-Governor are the questions marked Nos. 9, 11 and 12.

17. With respect to the first enquiry as to "the probable fair money value of water to the chief crops likely to require it," it is

evident the question has been misunderstood by the local Officers, for the reply which is given can refer only to the *rate*, which, in their opinion, may be charged, and cannot certainly be meant to represent the *value* of the water itself. That value is of course measured by the actual increased weight of crop raised by means of irrigation over that yielded without its aid, added to the increased *average* out-turn obtained in a series of years by removing the element of uncertainty, which now, more or less, affects all agricultural operations carried on in sole dependence on the rains.

18. The Collector of Burdwan reckons that increase at two-thirds, and, though the Collector of Hooghly has omitted to add the weight of irrigated crops, his statement of the produce of unirrigated lands corroborates that of the Collector of Burdwan.

19. The Lieutenant-Governor is disposed to think that the difference in favor of irrigated crops given by the latter Officer is certainly not exaggerated, so that if the value of an acre of produce be Rupees 20, that of the water, which increases that produce by two-thirds, would be represented by $13\frac{1}{3}$ Rupees, on which Rupees 1-8, the water-rate proposed in the Chief Engineer's Note, will be less than 12 per cent, and therefore a moderate demand.

20. As regards the point in the eleventh query, Captain Garnault remarks as follows:—

“All the principal Zemindars say they would second the aims of Government in inducing the cultivators to take the water.

“For my own part, I do not think much inducement is required, as the cultivators throughout the District are alive to the advantages of irrigation, and would, I think, at once avail themselves of it, provided the cost is not excessive and the distribution given when required, and without any trouble to the people taking it.”

21. It seems to the Lieutenant-Governor scarcely necessary for the subject treated in question No. 12 to be discussed in this letter, as it is one of general, rather than of local, application in this Province, where, with few exceptions, the permanent settlement has been carried out; and that, if any special arrangements in this system of charging for water are found to be necessary, there will be ample time for their consideration while the construction of the works is being carried on.

22. In conclusion, I am directed to add that there are at present a sufficient number of Executive Officers ready to make a commencement of the works as soon as they receive the sanction of the Governor General in Council ; but that it will be necessary to increase the Staff in the Assistant and Subordinate Grades. A Statement, however, of the Establishment requisite for this, and the other projects in Bengal, is under preparation, and will shortly be submitted.

Note by LIEUTENANT-COLONEL F. H. RUNDALL, R. E., Chief Engineer, Bengal, Irrigation Branch, on the Project of a Canal for Irrigation and Navigation from the Damoodah to the Hooghly,—(20th December 1868.)

The necessity for a canal from the Damoodah to the Hooghly has for some years been acknowledged.

2. Though the Damoodah is used during the rainy season to transport coal from the various collieries at Raueegunge, yet, owing to the spasmodic character of its freshets, and the strength of the current, it is, at its best, unfavorable for navigation. It is true that the current is in the direction of the trade, and, therefore, so far an advantage ; but it presents so great an obstacle to boats on the upward passage as to render the voyage tedious and proportionately expensive, and so the chief benefit of water communication, its cheapness, is lost. The construction of the East Indian Railway, it was thought, would supply a remedy for the defective navigation of the Damoodah ; but though it carries a large portion of the greatly increased coal trade, yet the river with all its faults and risks is still used as long as possible ; for, notwithstanding its defects, the cost of transport is somewhat lower than that which the Railway Company can afford to charge, while it possesses the great advantage of enabling the coal to be carried to the exact spot or vessel for which it is required, without incurring the expense and entailed by breaking bulk.

3. The consumption of coal has, moreover, increased so much of late years that it is found the Railway cannot, with the demand made upon it for the general traffic of the country, comply with the requirements of the Collieries. It is evident, therefore, that an effective canal available at all times of the year, and capable of being cheaply worked,

is best calculated to meet the requirements of a trade now annually increasing, and which cannot fail eventually to attain to large dimensions. Coal, however, is not the only article for which such a Canal is needed. The great extension of buildings in Calcutta and its Suburbs, and the demand of stone for paving and other purposes, have so raised the prices of materials as to make the use of stone nearly prohibitory. A line of communication therefore with that part of the country from whence stone, lime, and fuel can be cheaply transported has become an absolute necessity.

4. The Project did not assume a tangible shape until the year 1866, when a proposal was put forward by Messrs. Schiller, Peterson, and Goodenough, that the Government should grant them the sole right of constructing a Canal from the neighbourhood of Raneegunge to the Hooghly, with a request that the late Lieutenant-Colonel Short, R. E., who had interested himself in the Project, might be allowed to assist them in the preparation of the plans.

5. The Canal was not intended to be confined to navigation purposes, but was to carry water for irrigation likewise. The cost was estimated at a crore of Rupees, and the Promoters undertook to guarantee its completion within six years.

6. Their proposal, however, though supported with the recommendation of the Government, was not acceded to, as regarded the irrigation part of the scheme by the Government of India, who, nevertheless, expressed its willingness to consider favorably any Project designed for navigation purposes only. There were, however, certain difficulties in the way, and, amongst other, a previous proposal on the the part of the East India Irrigation Company to construct a Canal from the Damoodah in connection with their Orissa Project.

7. The proposal of Messrs. Schiller and Company was referred to the Secretary of State, who approved, in the main, of the reply given by the Government of India thereto, and those gentlemen were informed accordingly. Meanwhile the views of the Home Government, regarding the construction of Irrigation works for the country generally, had become more settled, and, as no further steps were taken by the above-mentioned Promoters of the scheme, the Government of India, in

anticipation of the organization of an Irrigation Department, called upon this Government to submit a list of such Projects as it considered deserving of investigation.

8. Amongst the schemes enumerated in the reply from this

Government was that of the Canal from
* *Fide* No. 341. of 10th March 1867.

Raneegunge, and orders* were accordingly received to put in hand, simultancously with the investigations which were being made by Lieutenant Heywood for Reservoirs in connection with the regulation of the Damoodah floods, the surveys and sections necessary for preparing designs and estimates for head works and canals from both banks of the Damoodah, including one for navigation to connect Raneegunge with the Hooghly.

9. No Officer was available until the return from England of Captain Garnault, R. E., who was accordingly entrusted with the work. He commenced operations at the beginning of last cold season, and has now submitted a complete set of surveys, plans, and estimates, accompanied with a clear report on the character of the Project, the engineering details of which I will now proceed to notice.

10. The general design of the works consists of a weir across the Damoodah opposite to Raneegunge, and nearly on the line of the Baucorah Road. A canal is led of from the left flank of the weir, and for the first 16 miles, as far as the village of Noadehee, is compelled, by the nature of the ground, to hug the margin of the river. From that point, however, it commences to trend away and run on the watershed of the country, more or less paralled with the line of Railway, until it reaches Burdwan, where it again skirts the river bank for about 10 miles, leaving it finally at the great bend above Hybutpore, from whence, gradually curving round, it runs to its terminus in the Biddabatty Khall at Serampore, measuring rather more than 100 miles in length.

11. The crest of the weir, and, therefore, of the surface of the water in the canal at the off-take, is 260.64 feet above mean sea. The water reaches the surface of the country at the 5th mile, and will from thence irrigate the small patch of land lying between the canal and the river bank, but it will not commence to throw out distributaries

so as to command any large areas until the 16th mile. The Index Map shows at a glance the size of the tracts comprised within the several drainage streams to which 13 principal distributing branches will be led, five of which will have to be carried across the Railway. The main canal itself, as at present designed, keeps to the south of it the whole distance.

12. Though terminating for the present at Serampore, I am of opinion that it will eventually be found desirable to continue the line to Calcutta, and, if the comprehensive Project of Wet Docks in connexion with the Port and Railway Junction Scheme, as proposed by Colonel Hyde, is ever carried out, the canal must, of course, be connected with them, and, indeed, should form the source of supply to the Docks, instead of their being made to depend upon the mud laden water of the Hooghly, for not only will great economy in first cost be thereby secured, but one of the principal objections and difficulties connected with the construction of Wet Docks be obviated, *viz.*, that of keeping them free from deposit. It may, perhaps, be advisable not to carry the canal so far even as Serampore at first, but to lead it instead to the Hooghly by way of the Sursuttee at Trebanee Ghaut. The saving in distance will be about 12 miles, but the cost will not be reduced more than one lac of Rupees, as only the earth-work will be saved thereby, for the terminus being at tide water the fall in the canal necessarily remains the same, and therefore entails the construction of the same number of locks. The connexion with the Hooghly might thus be effected a little more quickly, and the branch to Trebanee would even, after the extension to Calcutta, be still always useful.

13. The weir has been designed after the model of that lately built across the Mahanuddy at Cuttack, and all the attendant head works of sluices and locks are after designs which have there proved successful.

14. The weir itself is to be 10 feet high above the summer surface of the water, which is practically the low bed of the river, for the Damoodah is nearly dry during the hot season. A paved roadway, 18 feet broad, has been provided, as being on the line of the Bancoorah Road, it will probably prove very useful, for the large cart traffic that

takes place, to the Railway Terminus, and which now has to plough across three-fourths of a mile of heavy sand.

15. The under-sluices in the weir are designed after a pattern which is now being experimented upon in Orissa, and promises to be successful. If these are adopted, it will be necessary to construct annually a Trestle Bridge, or some temporary arrangement, to continue the communication across the gap formed by them in the weir, but this will be an easy and inexpensive matter.

16. The observed highest rise of the river at Rancegunge above the summer level is 20 feet. The weir being 10 feet high will occupy half the vertical height; but, owing to the inequalities of the river bed, not more than three-sevenths of the sectional area. The greatest afflux occasioned by the obstruction has been calculated at somewhat under $1\frac{1}{2}$ feet, when the discharge is at the maximum of what the most carefully ascertained observations can make it, *viz.*, 323,000 cubic feet per second. A greater discharge can only be obtained by a greater rise of flood, and as the river here cannot overtop its banks, every additional foot in height of flood only lessens the comparative amount of waterway obstructed by the weir, and therefore reduces the afflux proportionately.

17. The fall in the flood surface of the Mahanuddy at the site of the weir is about 1·8 feet per mile. That of the Damoodah at Rancegunge about 2·4 feet. The extreme rise and fall of the Mahanuddy at Naraje is over 30 feet, and at Cuttack 22 feet. That of the Damoodah, as above stated, is 20 feet. The theoretical mean velocity of the Mahanuddy at Naraje is 9·2 feet, and the surface velocity 11·5 feet per second, and at Cuttack 8 and 10 feet respectively; that of the Damoodah 8·82 feet for the mean, and 10·1 feet for the surface velocity. The depth of water over the weir at Naraje is 19 feet, at Cuttack 11 feet, at Rancegunge only 10 feet, so that the momentum of the water in the three cases, if represented by the velocity multiplied into the weight of column of water over 1 foot in length of the weir, would be, supposing the afflux over the weir to be equal in the three cases,—

$$19 \times 62\cdot5 \times 9\cdot2 = 10,925 \text{ feet.}$$

$$11 \times 62\cdot5 \times 8\cdot00 = 5,500 \text{ ,,}$$

$$10 \times 62\cdot5 \times 8\cdot82 = 5,512 \text{ ,,}$$

18. The trial on the Damoodah work will thus be slightly in excess of that on the Mahanuddy, but only half of that which the Naraje weir has to withstand. The section provided for the Ranee-gunge weir is therefore ample, and indeed need not be constructed to the full extent at the outset, but only added gradually, as the effect of each succeeding year's freshes may show to be necessary.

19. The head sluices are designed to discharge, with a head of 4 inches, 1,500 cubic feet per second, the capacity of the canal, so that, when the river is only level with the crest of the weir, there may be as little loss of depth in the canal as possible.

20. In order to carry the above quantity of water in full supply with only a moderate velocity, (a little over 2 feet per second,) the Canal must have a width at the head of 114 feet, and a depth of 7 feet. This width is maintained to the 49th mile, from whence to the terminus it is reduced to 90 feet.

21. The Locks have been designed 100 feet by 20 feet in width, so as to allow most of the boats which now ply on the Hooghly to navigate the canal, but the Coal Companies will, doubtless, in time construct a better description of boat, and as the traffic is certain to become very heavy, a clear width of 90 feet at the water line will not be too great. A reduction in width from the point where the principal amount of irrigation ceases will not materially affect the estimated cost of earth-work, and therefore I am of opinion it is worth while to have the wider canal.

22. The Falls and Locks have been arranged so as in the summer season, when the supply in the river falls short, to secure a minimum depth of 5 feet on the Lock sills, quite sufficient to afford an effective navigation. The designs and arrangement of these works are also after the model of those in Orissa.

23. In the first 20 miles of its course, the canal unavoidably passes over very uneven and rough ground, thereby rendering high embankments necessary, though but for short distances. These will have to be carefully constructed, but there is good stiff earth not far from them all, and the silty water of the Damoodah freshes will very

quickly them and fill up the hollows uniform with the general bed of the canal.

24. As it is not possible to give a greater headway to some of the aqueducts, they have been provided with substantial floorings, and their waterway has been calculated at a maximum so as to secure the least possible accession of velocity through the arches.

25. The general arrangement and designs of the works were all carried out in personal communication with myself, and are fully described in the Executive Engineer's report. It is only necessary to observe that I have reduced the width of the aqueducts, which had been made too large, to 50 feet in the clear, thereby reducing the cost of those works considerably. The original drawings submitted by the Executive Engineer have not been altered, in order to save further delay in the submission of the Project, but the necessary corrections have been made in the estimate.

26. The estimate, as submitted by the Executive Engineer, amounts in aggregate to Rupces 45,24,816, composed of the following items:—

	Rs.	Rs.	Rs.
<i>Earth-work—</i>			
Canal ...	...	18,40,238	
Distributaries ...	...	4,00,000	
<i>Masonry—</i>			
Head Works ...	5,33,527		
20 Locks ...	6,12,000		
3 Aqueducts ...	2,76,156		
5 Large Culverts ...	82,485		
60 Small ditto ...	1,61,400		
10 Bridges ...	1,17,410		
		17,82,978	
Altering Railway Bridge ...	1,00,000		
Cost of land ...	4,01,600		
			45,24,816

27. This estimate is much higher than I anticipated. On analyzing it, I find that the rates allowed for the different kinds of work are high, and, in my opinion, unnecessarily so. The Executive Engineer, however, has represented that the Railway works in the vicinity have cost as much, if not more, and therefore begged that the rates might be allowed to stand.

28. The earth-work to the canal, as estimated, will cost Rupees 18,400 per mile, thus—

	Rs.
The aggregate cost of cutting amounts to ...	6,79,643
Ditto ditto Embankments ...	10,72,965
	<hr/>
	17,52,608
Contingencies at 5 per cent ...	87,630
	<hr/>
Total for 100 miles ...	18,40,238
	<hr/>

29. It is true that the surface width is 114 feet for the first 40 miles, and 90 feet for the remainder ; but, on examining the details for each mile, I find the following :—

- I.—17 miles consist of cutting only.
- II.—43 „ „ of „ and embanking.
- III.—40 „ „ of embanking only.

30. The cost per mile of—

		Rs.	Rs.
No. I. ...	Averages ...	...	19,996
That of No. II. ...	{ Cutting ...	7,748	
	{ Embanking ...	6,953	
		<hr/>	14,701
That of No. III. ...	... ..	...	19,037

31. The principal portion of the expense thus appears to be in the embanked portions, and as these last considerably exceed the cost of excavation, it is evident a better distribution may be made of the relative lengths of excavation and embankment. An examination of the longitudinal section shews where improvements can be made by a more

judicious arrangement* of the Locks, and a saving of at least Rupees 2,00,000 may be effected.

32. To lessen the expense of the cuttings, by reducing the width of the canal, will, of course, contract its usefulness and the area from which returns can be collected ; but in carrying out the Project, it may be advisable at first to limit the surface width in the cuttings to 75 feet, by doing which the cost would be reduced by Rupees 2,56,100 made up as follows.

33. In 29 miles of the upper half a reduction of 39 feet in width gives an average sectional area of 327 square feet, estimated at 4 Rupees per 1,000 cubic feet. In 9 miles of the lower portion a reduction of 15 feet in width lessens the sectional area by 120 square feet, also estimated at 4 Rupees, and in 17 miles a reduction of 122·7 square feet in the items estimated at 3 Rupees per 1,000 cubic feet would be effected.

34. The mileage and aggregate amount by which this portion of the estimate could be reduced then appears to be—

			Rs.	As.	P.
29 miles at 6906·24	...	...	2,00,281	0	0
9 ditto at 2534·40	...	...	22,810	0	0
17 ditto at 1943·56	..	...	33,009	0	0
Total			2,56,100	0	0

This sum, added to that which may be saved by a more judicious location of the Locks, or Rupees 2,00,000, would lessen the estimate for the earth-work by Rupees 4,56,100.

35. The cost of the weir and head works is set down at Rupees 5,33,527 exclusive of Plant, or, as the length of the work is 3,000 feet, Rupees 177 per running foot. The cost of the Mahanuddy weir, 6,600 feet long, inclusive of Plant, has been Rupees 130. The latter is 12 feet high, while that of the Damoodah is only 10 feet. Much of the stone in the Mahanuddy work, however, was conveyed by water.

36. The cost of the Locks, inclusive of the attendant weirs, is given at Rupees 3,000 per foot of lift. This may probably be correct when taken along the whole length of the canal. The three principal aqueducts are estimated at Rupees 2,76,156. For the area of country drained, they appear to me to be unnecessarily large, but it is well to be on the safer side in designing such works, and therefore I have not thought it necessary to reduce the waterway of the arches. The items for large and small culverts are not higher than probably is necessary. Ten separate bridges have been provided, besides which there will be a bridge over the tail bay of every Lock, which will add 20 more crossings for the canal, thus giving one on an average at every $3\frac{1}{2}$ mile. If more crossings are wanted they should be supplied by ferry boats.

37. The cost of the Distributaries has been reckoned at what such works have cost in Orissa, *i. e.*, Rupees 2 per acre *commanded*.

38. The cost of land has been set down at Rupees 120 per acre, which at 15 years' purchase gives a supposed rental of 8 Rupees per acre, a larger rent, I should imagine, than the land passed through would average, as a good deal of it is waste. It will be necessary to place experienced and careful Assessors on the duty of acquiring land not only in connection with this but with all the Projects now contemplated for this Province.

39. The Executive Engineer has not included any item for Tools and Plant in his estimate. The contingencies, when abstracted from each item, amount to Rupees 1,67,000, but this would not be sufficient to provide such special plant as is required in the construction of weirs across large rivers. A sum of Rupees 2,00,000 should, therefore, be added to provide for Rails, Waggon, Cranes, Workshop apparatus, and Tools.

40. No allowance has been made for Bungalows for the Engineers and Subordinates while the work is under construction, and for this a sum not less than Rupees 1,00,000 will probably be required.

41. An item for making temporary Dams in the river while the weir is building should likewise be added, and a further special sum for unforeseen contingencies, such as injuries by untimely and sudden freshes during the working season. For these two purposes not less than Rupees 2,00,000 should be added.

42. The item for Superintendence has also been omitted, but though, in the ordinary class of works carried on in the Public Works Department, no such allowance is permitted in estimates, yet, on these large Projects, I am of opinion provision should be made, and the cost of the establishments, if not the members composing them, should be separately shewn. I am of opinion that to carry out this Project vigorously and effectively an establishment amounting to at least Rupees 10,000 per month will be requisite, and as the work would probably not be completed under three years, a sum of Rupees 3,60,000 may be considered as required for supervision.

43. Collecting these items, then, the following will appear as the total first cost of the Project:—

Rs.		
By Executive Engineer's estimate ... 45,24,816		
<i>Add—</i>		
Tools and Plant ...	...	2,00,000
House accommodation ...	...	1,00,000
Temporary Dams and Cuttings ...	...	2,00,000
<hr/>		
Total ...	...	50,24,816
Supervision ...	...	3,60,000
<hr/>		
Total ...	...	53,84,816 or say 54,00,000
<hr/>		

44. The subsequent annual charge for maintenance and repairs may be safely taken at 5 per cent on the actual cost of construction. It does not amount to that sum, I believe, on the Godavery Works, where the original cost was much less, and where, therefore, the maintenance would, of course, form a larger percentage. Excluding the cost of the land and plant, or Rupees 6 lacs, the outlay may be assumed in round numbers at 48 lacs, 5 per cent on which would be Rupees 2,40,000. To yield a *nett* return of 10 per cent, the income must realize Rupees 4,80,000 more, or Rupees 7,20,000 in all.

45. In Section VIII. of the Executive Engineer's report will be found the sources from whence income is derivable. I think he has

considerably under-rated it, and I fully believe it will prove much larger eventually.

46. Supposing the canal to be made of the capacity designed, it will admit of the full irrigation of 200,000 acres of rice during the monsoon. For this Captain Garnault proposes a charge of 8 annas per acre; but if irrigation is needed at all, a question sufficiently answered by the Rain Tables appended to the report, and which will be analyzed presently, and practically demonstrated by the experience of the present year, it is quite certain that its value is much more than 8 annas per acre. In Midnapore and Panchkoora, on the Irrigation Company's Canal, Rupees 2-8 has been paid, and I think, therefore, 8 annas per beegah, or Rupees 1-8 per acre, will be quite readily acceded to. For the cold weather crop, the price of 3 Rupees may fairly be asked; but except for such crops as sugar-cane, tobacco, and the vegetable gardens near Calcutta, a higher rate would probably not be obtainable, or even desirable. The area irrigable by the available supply of water is probably correct, and, as far as the present Project is concerned, is the maximum to be expected. Any increase on the cold weather area must be supplied from the contemplated Reservoirs, and the water-rates leviable therefrom will, of course, be credited to those works.

47. An examination of the Rain Tables for Calcutta and Burdwan shews the following quantities as falling during the cultivating season from June to October at the respective localities :—

		Calcutta.	Average of good Season.	Burdwan.	Average of good Season.
1859	59·30	38·8*	57·70
1860	47·84*	50·7*	
1861	73·92	77·0	
1862	63·93	54·25	
1863	52·06*	40·55*	
1864	67·55	37·10*	
1865	37·10*	34·70*	
1866	55·72*	49·85*	
1867	62·93	50·35*	
1868	79·64	64·10	
			67·88		

NOTE—The years in which the total rainfall was below the average and those in which it failed in the month of October are marked thus *.

The first thing remarkable in the above table is the great difference in the total quantity falling at two places so short a distance apart, and its diminution westward of the meridian of Calcutta. It is noticeable also that in Calcutta the quantity of rain was much below the average in four years, and in Burdwan in seven years out of the above period, but what is still more observable and indicative of the necessity for artificial irrigation always being available in rice-growing countries is the uncertainty and scarcity of rain in the month of October by which the whole of the transplanted rice constituting the main crop of Lower Bengal is imperilled. By a deficiency of rain in that month, the outturn, if not altogether lost, is seriously diminished. The following shews the quantity registered in October during the last 10 years :—

			Calcutta.	Burdwan.
1859	..	..	4.96	3.60*
1860	..	..	1.68*	3.60*
1861	..	..	7.75	11.20
1862	..	..	14.40	12.65
1863	..	..	3.48*	2.00*
1864	..	..	6.50	0.80*
1865	..	..	0.00*	0.00*
1866	..	..	7.83	2.20*
1867	..	..	8.12	5.35
1868	..	..	1.53*	1.00*

From the above it will be seen that though 80 inches fell this year in Calcutta, and 64 in Burdwan, between June and September, only 1.53 and 1.00 inch fell in October; hence the short out-turn and apprehensions of scarcity, notwithstanding the super-abundant rain in the previous month.

48. I should place the eventual returns from irrigation, therefore, at—

	Rs.
200,000 acres monsoon rice at Rs. 1-8 ..	= 3,00,000
64,000 acres cold weather crops at Rs. 3 ..	= 1,92,000
	<hr/>
	4,92,000

NOTE.—The years in which the total rainfall was below the average and those in which it failed in the month of October are marked thus *.

49. From navigation, I consider, a much larger return may be looked for than Captain Garnault has assumed. The quantity of coal raised annually at the Raneegunge Collieries is stated to be about 300,000 tons, of which only 46,000 tons are taken by the river route; but I have been furnished with a Statement by the Managing Director of the Bengal Coal Company, which shews the actual *consumption* of coal last year to have been a little short of 500,000 tons. Even now the Railway Company are unable to comply with the demands of the Collieries, and, as justly remarked by Captain Garnault, it is perfectly certain that the opening of the Chord Line will only increase the Railway Company's difficulties. The supply for their own wants will doubtless be taken from the Kurhurballee Quarries, if they do not convey that which will be raised there for the public also, and therefore, without allowing for any increase in the quantity raised by the Collieries at Raneegunge, it seems also certain that at least $\frac{2}{3}$ ds, if not the whole, of the above mentioned 300,000 tons must be carried along the canal. It is not possible to state what amount of other articles will take the canal route; but, judging from the traffic which passes through the East India Irrigation Company's Canal at Oolabarria, at least 100,000 tons of stone and lime, and not less than 200,000 tons of grain and sundries may be expected, on which a toll of 8 annas per ton will probably be realized. With the Railway running parallel to the canal, it may be thought that passengers will not proceed by the latter; but of this I am by no means sure. The fare by the Rail is 3 pie per mile; by the canal they will be carried for 1 pie; and though the revenue from this source may be disregarded, I fully expect to hear eventually that it forms by no means an insignificant item.

50. The revenue from navigation may then be fairly expected to amount to—

Rs.			
200,000 tons of Coal at 1 Rupee	...	2,00,000	
100,000 tons of stone, lime, &c., at 1 Rupee		1,00,000	
200,000 „ sundries	...	1,00,000	
			<hr/>
			4,00,000
			<hr/>

51. The aggregate income eventually available from both sources of irrigation and navigation will thus amount to Rupees 8,92,000, or Rupees 1,72,000 more than as above shewn is requisite to provide 10 per cent *net* on the outlay for the Project as designed.

52. In connexion with this scheme, however, especially if such an outlay as half a million sterling be incurred, it would be manifestly impolitic not to make the fullest use that the capacity of the canal will admit of for the irrigation of a cold weather crop.

53. Supposing that only 200 acres are irrigated per cubic foot of discharge, the canal, if maintained at full supply, would secure 300,000 acres, from which if 40,000 acres, the quantity that might be reached by the present volume available from the river, be deducted, there would remain 260,000 acres to be supplied by Reservoirs, which, at Rupees 3 per acre, would yield an income of Rupees 7,80,000, and furnish about 14½ per cent interest on an outlay of 54 lakhs of Rupees.

54. A volume of 1,500 cubic feet per second would amount to nearly 130 millions cubic feet per day, and, if required for 150 days, would necessitate an available storage of 19,500 millions cubic feet, or more than the quantity which I showed in my Note on Lieutenant Heywood's Report would exercise an important influence in regulating the Damoodah floods. To provide a discharge of 19,500 millions cubic feet over the 150 days would probably require the actual storage of about $\frac{1}{3}$ rd more, or say, roughly, an aggregate of 26,000 millions, which if it cost 54 lakhs would allow the excessively high rate of Rupees 207 per million, or nearly 4,830 cubic feet per Rupee.

55. Hence it would unquestionably be a mistake not to prosecute the reservoir scheme in connection with this Project, as, unless I am much mistaken, the cost of storage will not amount to half that rate; and, if so, nearly the whole quantity of water requiring to be restrained, in order to render the Damoodah floods quite harmless, could be remuneratively stored, even supposing that none of it were utilized in any other locality.

56. There is, however, a large area irrigable on the right bank of the river, to which the surplus of the storage could be advantageously led during the cold weather, and thus the two-fold object which the

Government has in view in connexion with the Damoodah, *viz.*, security against both floods and drought, would be attained, together with an adequate return for the outlay incurred.

From the Government of India, to the Government of Bengal,—
(22nd March 1869.)

With reference to your No. 11357. dated 29th December 1868, submitting designs and estimates for a canal from the Damoodah to the Hooghly, I am directed by His Excellency the Governor General in Council to convey to the Government of Bengal sanction to proceed at once with the necessary preliminary measures for commencing the weir at Raneegunge and the works in connexion with it.

2. The land required for the head works and first five miles of canal, and for the tramway leading to the quarries, may at once be marked out and possession obtained, and operations begun. Also needful steps may be taken for procuring the tools, &c., likely to be required.

3. Further instructions in detail will be issued as soon as possible after the Government of India arrives at Simla, but these are not likely to affect any operations that could be now set in hand.

4. The Governor General in Council desires me to express a hope that the local coal proprietors, whose interests this canal will in so great a measure benefit, may be disposed to give all reasonable facilities to the Government in the execution of the works, and will permit the quarrying of the stone required for the weir on their estates either without charge or for a nominal sum.

5. His Excellency in Council will also hope that the land required for the works may be furnished on terms which shall be favorable to the Government, and that the proprietors will be content to receive such a sum in compensation as will simply be equivalent to the loss of income occasioned by the occupation of the land by the canal.

6. It seems necessary to direct special attention to the question of the under-ground rights in the land taken for this canal. It does not appear desirable to acquire such rights from the surface owners, but

measures should be ~~taken~~ to cause any coal workings, &c., to be so carried on as ~~not~~ to injure the canal works. How this object can best be attained will require the careful attention of the legal advisers of the Bengal Government.

From the Government of Bengal, to the Managing Director of the Bengal Coal Company,—(No. 427I., dated the 30th March 1869.)

In conveying sanction to the project of a canal from the Damoodah to the Hooghly, the Governor General in Council has intimated a hope that the local coal proprietors generally, whose interests will be so much benefited by this canal, will be disposed to give all reasonable facilities to the Government in the execution of the works, and will permit the quarrying of the stone required for the weir across the river without charge, or for a nominal sum. His Excellency in Council also hopes that the land required for the works may be furnished on terms which shall be favorable to the Government, and that the proprietors will be content to receive such a sum in compensation as will simply be equivalent to the loss of income occasioned by the occupation of the land by the canal.

2. In conveying these sentiments of the Governor General in Council, the Lieutenant-Governor desires me to express his hope that they will be liberally responded to by your Company.

From the Government of Bengal, to the Superintendent of Works, Damoodah Circle,—(15th April 1869.)

With reference to the accompanying extract* from a letter from the Secretary to the Government of India, Public Works Department, marginally noted, conveying sanction for commencing operations on the Canal Works, I am desired to forward the accompanying Memorandum of Instructions prepared by the Chief Engineer of Irrigation for your guidance, and to direct your careful attention to the several points adverted to therein.

* Paragraphs 1 and 2.

No. 97I., dated 22nd March 1867.

Memorandum by LIEUTENANT-COLONEL F. H. RUNDALL, R. E., *Chief Engineer, Bengal, Irrigation Department, on the letter from the Government of India No. 97I., dated the 22nd March 1869,—*
(30th March 1869.)

With reference to the sanction of the Government of India, conveyed in No. 97I. dated 22nd March 1869, to proceed at once with the preliminary measures for commencing the weir at Raneegunge and the works in connexion with it, the following instructions are issued for the guidance of the Superintendent of Works, Damoodah Circle.

The works which will now require to be put in hand are—

- 1st,—Construction of the buildings at the weir site for the accommodation of Officers, Subordinates and Artificers, Work-shops, &c.
- 2nd,—The quarries and line of tramway therefrom to the river.
- 3rd,—Collection of material, such as limestone, fuel, timber, and bricks for the wells.
- 4th,—Purchase of Work-shop and other Plant and Tools.
- 5th,—Marking out the boundaries of all the land required in connexion with the above.
- 6th,—Marking out the centre and side widths of the first five miles of the canal.
- 7th,—The collection of the Subordinate Establishment required for the work to be now undertaken.
- 8th,—The accounts.

As regards the accommodation, a plan of the ground to be occupied should be first drawn on a large scale, and convenient plots allotted for all the buildings, according to the purposes for which they may be respectively devoted. Plans and estimates should then be submitted for the formal sanction of Government. In the meantime the collection of materials should be proceeded with, and contracts be given for the doors and windows, if by so doing they can be more quickly and as economically procured as if made on the spot.

2nd. The site of the quarries should be well examined, and trial openings made before definitely fixing the direction of the portion of tramway nearest them. The rest of the line to the river should, after being carefully levelled and marked out, be at once put in hand, so that the embankment may have time to get well consolidated before the ballasting is laid on. The actual breaking ground on the quarries or elsewhere must of course be contingent on the permission of the proprietors of the land to enter on the ground prior to its being formally taken over for Government.

3rd. Contracts should be entered into for the supply of such materials as have to be brought from a distance, such as timber or limestone; but the expense of obtaining the latter in the neighbourhood by the Department's own agency should first be well tested, and the material should not be carried one mile further than can possibly be helped. All the lime must be used quite fresh, and should be burnt at the site of the works. Kilns should, therefore, be erected on both sides of the river, if necessary.

Timber for well curbs should be procured, but experiments should be made as to whether the curbs could not be made of whole bamboos. It is not necessary that the well should be circular, and experimental wells might also be built with rubble stone. Similar experiments are now being made on the Sone, and their success or otherwise should be ascertained. If the rubble wells answer, it will save considerable expense in the manufacture of bricks.

4th. A list of the most necessary machines, sufficient for the wants of a small work-shop, as well as of those required for the quarries and tramway, should be prepared, and such as are procurable in Calcutta may, after the sanction of Government has been obtained, be purchased. Care will have to be exercised in the selection of the machines, as well as of the ordinary tools. The best brands only of the latter should be purchased.

5th. Great care should be taken in marking out the boundaries of all the land required for the works, so that, while ample is secured for all the respective purposes, not more than is reasonably necessary be

taken up. The necessary sketch plans should be prepared, showing the village or mouzah boundaries, in order to guide the Deputy Collector who will be appointed to take up the land for the works. All the Land Plans should be carefully numbered in consecutive order for the respective works for which the land is taken up, so as to be easily recognizable hereafter whenever a necessity for reference may arise.

6th. The centre and side widths of the canal itself for the first five miles will have to be carefully nicked out before the Deputy Collector can commence his measurements, and at the same time the centre line can be pegged out so as to admit of the excavations being commenced immediately the promised further detailed orders are received from the Government of India.

7th. The Superintendent must carefully consider the subordinate establishment which will be necessary. He will submit lists of such as, in his opinion, will be requisite, together with the names of any candidates who may have applied to him, and whom he can confidently recommend. Only such appointments will be filled up at present, however, as are absolutely necessary in connexion with the quantity of work to be undertaken. A person who has had experience in the quarrying of laterite and management of the tramway at Cuttack will be transferred to Raneegunge.

8th. The Superintendent will have to make at the outset such arrangements as will ensure a careful record of the expenditure being kept. He must report what arrangements are required in connexion with the supply and custody of cash. At present, while the expenditure will be moderate, the ordinary Account Establishments for the Division will probably suffice; but, if it is found hereafter that some more special establishment is required, the Superintendent must report the same for the consideration of Government.

It will be useful if a diary containing all particulars of interest in the progress of the work were regularly kept by the respective Executive Engineers, so that hereafter a history of the project from its commencement may be forthcoming and prove a valuable reference for subsequent similar undertakings.

From the Managing Director, Bengal Coal Company, to the Government of Bengal,—(5th April 1869.)

Your letter No. 427I. of the 30th ultimo has been duly received and laid before the Board of this Company.

In my letter of the 1st December I stated the terms on which any lands belonging to this Company would be made over to you for the canal works, and I have now only to add that for all lands not cultivated no demand will be made.

I think I stated to you verbally that the Directors have no legal power to sell any land of the Company, and that the arrangement stated could only be made by them on the plea that the land required for the canal could be taken under the Public Works Act, and that, by thus agreeing to part with it on already fixed terms, time would be gained in the construction of a work generally for the benefit of the Company.

If you will be so good as to let me have a copy of the plan of the canal as far as it passes through the property of this Company, I will at once send you a memorandum of what the cost of the land would be, and endeavour to meet your views in all ways possible.

As to the laterite and other material required for the weir, the same remark applies, that the Directors could not give it without some charge; but I should be ready to make this quite a nominal one, if you could offer some collateral advantage to this Company in lieu of a larger payment. I would beg to suggest that, as I believe you will lay down a tramway from Munglepore to Rogoonauth Chuck, you might agree to let this Company have it on certain conditions when the work was done, or the use of it on favorable terms; or, as you will require a large quantity of rubble coal, you might engage to buy it of this Company at a fixed and fair price.

The Board are quite anxious to meet you in every way possible, and will be glad to receive any proposals you can make of the nature indicated.

From the Government of Bengal, to the Government of India,—(15th April 1869.)

With reference to your letter No. 97I. dated 22nd March last, conveying sanction to the commencement of preliminary operations on

the Damoodah Canal Project, I am instructed to say that the purport of the wishes of the Governor General in Council, as expressed in paragraphs 4 and 5, have been duly conveyed to the Managers of the Coal Companies.

2. I am now to forward a printed copy of a reply* from the Manager of the Bengal Coal Company, intimating the willingness of the Directors to meet the views of His Excellency the Governor General in Council, but asking for some "collateral advantages" to be conceded in return.

* Letter dated 5th April 1869.

3. The terms alluded to, as those on which the Directors had previously intimated their readiness to make over all the requisite land, are contained in the letter from Mr. Robinson dated 1st December last, herewith forwarded.

4. The concessions now solicited are either the use of the tramway about to be constructed from the Laterite Quarries to the River, or an "engagement" to buy all the coal required in connexion with the proposed works at "a fixed and fair price" from their Company.

5. With reference to the first of these concessions, I am desired to state that the Lieutenant-Governor is of opinion there can be no objection to making over the use of the tramway to the Company on the understanding that they keep it in proper repair; but, as regards the second point, he is doubtful of the expediency of entering into an engagement with one Company only, and is of opinion that, for the coal required, tenders ought rather to be publicly called for.

6. I am desired to solicit instructions as to the extent to which the concessions asked for may be granted.

From the Government of Bengal, to the Managing Director, Bengal Coal Company,—(17th April 1869.)

I am instructed to acknowledge receipt of your letter No. — dated the 5th current; and to state that the Lieutenant-Governor has

submitted, it for the orders of the Governor General in Council, with reference to the concessions asked for therein. The Superintendent of the Damoodah Circle has, at the same time, been requested to furnish you with a copy of the plan of the canal, shewing its general direction.

From the Government of India, to the Government of Bengal,—
(11th May 1869)

I am directed to acknowledge receipt of your letter No. 607I. dated 15th April 1869, requesting instructions as to the extent to which certain concessions asked for by the Directors of the Bengal Coal Company in connection with the projected new canal from the Damoodah to the Hooghly may be granted.

2. In reply I am directed to state that the Governor General in Council will leave it to the Hon'ble the Lieutenant-Governor to deal with the Coal Company as seems to him best, merely remarking that it is desirable that the Company should be treated well if they are disposed to be liberal, and that it does not appear *essential* to go into the public market for the coal required for the works if a really fair price is agreed to by the Company.

2. I am also to observe that it is very desirable that all minor matters should, as far as possible, be settled *at once* and the works begun.

From the Government of Bengal, to the Managing Director, Bengal Coal Company,—(15th June 1869.)

In continuation of my letter No. 615I. of the 17th April last, and with reference to the concessions asked for in your letter of the 5th idem,

I am directed to inform you that the Lieutenant-Governor will be prepared to give your Company the use of the tramway which is about to be laid down from Munglepore Quarries to Rughoonauth Chuck, in consideration of the nominal charge on which he understands your Company are prepared to make over the laterite and other materials required for constructing the weir and canal works. The tramway will of course be kept in repair by your Company as long as it may be required for their purposes.

2. The Officer in charge of the works will likewise be instructed to arrange for the purchase at a fair price of coal from your Company, whenever it can be conveniently transported to the site of those works for which it may be required.

From the Managing Director, Bengal Coal Company, to the Government of Bengal,—(24th June 1869.)

I am desired by the Board of this Company to say, in reply to your letter No. 11117. of the 15th instant, that you do not engage to leave the tramway from Munglepore to Rughoonauth Chuck for the use of the Company as long as they require it.

If you will do this, the Company will accept your conditions that they are to keep it in repair as long as they require it for their purposes.

From the Government of Bengal, to the Managing Director, Bengal Coal Company,—(1st July 1869.)

In reply to your letter of the 24th ultimo, I am directed to state that my letter of the 15th idem was intended to convey that your Company should have the use of the tramway from Munglepore to Rughoonath Chuck as long as they may require it.

From the Managing Director, Bengal Coal Company, to the Government of Bengal,—(3rd July 1869.)

I have to thank you for your letter of the 1st instant, which is quite satisfactory. I will send orders at once to the General Manager of this Company at Raneegunge to make over the laterite hill at Munglepore to Captain Garnault, and I shall be glad if you will instruct him to agree to the following conditions regarding it :—

1st,—The ground within which he wishes to work to be marked out by him at once.

2nd,—No cultivated land to be interfered with if it can possibly be avoided, and if any such is injured or occupied in any way, compensation to be made to the ryots at the established rates in the district of the value of the land.

3rd,—The sum of fifty Rupees (Company's Rupees 50) to be paid to this Company for the right to work the laterite for five years.

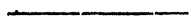
These conditions I hope you will consider reasonable.

With regard to land required for the tramway from Munglepore to Rughoonauth Chuck, I beg to say that this Company will not require any payment for the part of it that is uncultivated, and that, as soon as Captain Garnault marks out what he will require of this description, I shall be glad to give orders for it to be made over to him to work upon.

From the Government of Bengal, to the Managing Director, Bengal Coal Company,—(12th July 1869.)

In reply to your letter dated 3rd instant, I am directed to inform you that Captain Garnault has been instructed to comply with the conditions therein mentioned as far as possible.

DAMOODAH CANAL PROJECT.



Part II.

DAMOODAH CANAL PROJECT.

From the Government of India, to the Government of Bengal,—
(No. 2347, dated Simla, the 29th July 1869.)

In my letter No. 977, dated the 22nd March 1869 the sanction of His Excellency the Governor General in Council was communicated to proceed with the necessary preliminary measures for commencing upon the head-works of the Damoodah Canal, and the Government of Bengal was informed that further instructions in detail would be issued as soon as possible.

2. I am now directed to state that, after a careful consideration of the reports and correspondence on the project, and of the remarks conveyed in the accompanying Note by the Officiating Inspector-General of Irrigation, His Excellency the Governor General in Council is of opinion that sanction for the further prosecution of the works must be withheld until more full and satisfactory information than has yet been furnished on various important points is placed before the Government of India. The Governor General in Council will not object to the line of the canal being marked out, but the actual prosecution of the works should be deferred until the estimates can be revised, and until the dimensions of the main channel and the arrangements for the distribution of the water are more exactly stated, and finally approved of.

3. The estimates, as they stand at present, though probably giving a fair first approximation to the cost of the works, cannot be considered as at all complete. The designs for all the locks and weirs seem to call for further attention, and specific designs for each work are essential. It may also be remarked that the fall, according to the arrangements now proposed, would, so far as can be understood, in some cases be inconveniently great.

4. The arrangements for the distribution of the water and the tracts of land which are to be irrigated are only very faintly sketched out, and the cost has not been at all accurately ascertained. The precise alignment of the subsidiary channels does not appear to have been considered or determined on, though, of course, the question of cost must be materially affected by the nature of the ground through which these channels will be carried.

5. The average available supply during the rains seems to be about 4,000 cubic feet per second. Of this, 3,000 cubic feet per second might be set aside for the north or left bank of the river, and 1,000 cubic feet for the south bank. If the works are now designed so as to admit of future expansion, there is no objection to beginning with the smaller supply of 1,500 cubic feet on the left bank; but special attention will be necessary to the method of dealing with the falls and other masonry works, if provision is made for doubling the supply at some future period.

6. The question of reservoirs has been under consideration in relation to this project. The extent to which a cold weather supply of water could be utilized is not at all fully discussed in the reports now submitted, nor the extent to which the natural river supply would go in providing for it *without* reservoirs. It seems probable, however, from the information now before the Government of India, that in six years out of eight the reservoirs would probably not be needed; and if this is correct, it is very doubtful how far their cost would be covered by returns from irrigation. To render the project complete, however, it is very desirable that the Government of India should be placed in possession of information which will allow of a final decision being arrived at with regard to these works.

7. The proposed arrangements for combined irrigation and navigation in the main canal should be carefully re-considered, and I am to invite the special attention of His Honor the Lieutenant-Governor to the suggestions of the Officiating Inspector General on this point.

8. With regard to the terminus on the Hooghly, nothing has been said in the reports as to the precise reasons which led to the selection of the site near Serampore. It is understood that the interests of the coal owners would be best provided for by carrying the terminus as high up the Hooghly as Tribenée Ghât, so as to get as near to Chogda as possible. This last place is the point where the Raneegunge coal would be put on the Eastern Bengal Railway. The Hooghly below it is easily navigable, and the coal boats would drop down to Calcutta with the tide with perfect ease and safety. By taking the terminus at this point, about ten miles of canal would be saved, also some extent of land, which must get more costly as we approach Calcutta. The money saving would thus be considerable, and the line is also about the shortest possible from Burdwan to the Hooghly.

9. On the above grounds, His Excellency the Governor General in Council is of opinion that Tribenée Ghât is the proper site for the terminus, and I am to request that the lower section of the canal may be modified accordingly, unless the Government of Bengal, on further enquiry, can show that the above position is erroneous.

10. The Governor General in Council is disposed to think the proposed navigation rate, 1 Rupee per ton, as likely to be too high for the 100 miles of canal, and His Excellency in Council doubts the propriety of having more than half this rate. But on this point I am to observe that it is desirable that the probable cost of haulage should be ascertained, and that an accurate comparison between the railway and canal rates should be instituted. This must be a consideration materially affecting the designs of the works, as it cannot otherwise be known to what extent it may be desirable to make the arrangements for irrigation subordinate to those for navigation along any portion of the canal. The facilities in the way of sending coal to the Hooghly by the Damoodah during floods appear to have been somewhat understated in comparing this mode of conveyance with the railway and the new canal.

11. With regard to the coal traffic, it must be recollected that the rail in every case can be carried to the pit's mouth, and is in fact in some instances there already: also that at the same time regularity of transmission may be considered certain, and can be easily arranged to suit the ordinary rules of supply and demand. In the case of the canal, on the other hand, there must be land carriage from the pit's mouth to the bank, and trans-shipment is, therefore, inevitable. His Excellency in Council attaches no importance to the statement that the railway cannot carry the quantity of coal produced, and must suppose that the assertion to that effect made in Colonel Rundall's Memorandum must have been put forward inadvertently, as the carrying capacity of a double line of rail, with sufficient sidings and under good management, is nearly unlimited.

12. The question as to whether steam power will eventually be used on the canal, either for towage or carriage, must at present be a matter of surmise, and must depend on so many questions now unsettled, that the Governor General in Council does not believe that any one is capable of forming a very decided opinion upon it.

13. On the subject of the probable returns from the water used for irrigation, I am to observe that the acreage of both rice and rubbee crops per cubic foot of supply would seem to be over-estimated. But as the rice irrigation rate is low, and the volume of water in the rubbee is probably under-estimated, the general results may not be far out, or even not high enough as an ultimate return.

14. But before His Excellency the Governor General in Council can feel satisfied that the calculated returns rest on a firm basis, I am to remark that the questions which have been raised in the Officiating Inspector General's Note will have to be carefully considered and replied to. The point on which the least information exists is, after all, the most important, and that is, whether the waters of the canals can be fully utilized without an entire alteration of the system of irrigation now pursued in the lands effected. It would be a strong argument in favor of the project, if it could be shown that the people could be induced to give up their present defective system, and that irrigation of a superior kind could be immediately afforded to them, which, being also combined with efficient drainage,

would probably contribute vastly to the general healthiness of the country. *

15. It appears to His Excellency in Council that, unless a great change is effected in the present system of husbandry, the pouring of the waters of the Damoodah over these Districts might prove absolutely injurious. There is, therefore, much still to be considered in this matter, and His Excellency in Council desires that the Bengal Government should take a very early opportunity of submitting the opinions of the District Officers on this branch of the question.

16. It would, no doubt, be a difficult undertaking to interfere with a system of cultivation extending over a large tract of country, however imperfect that system may be, and further difficulties may be encountered in dealing with proprietary rights with regard to water-supply; but if a system of irrigation, pernicious to health and inadequate to proper agriculture, is in existence, the legislature, acting in the interests of the people at large, would have a perfect right to step in and substitute one of a more beneficial character.

17. It seems almost certain indeed that the extension of irrigation in Bengal can only go on under cover of legislative authority, which must admit of surface drainage being insisted upon, and the levy of water-rates on all land irrigated from water drawn from any Government canal originally, whether it has passed through fields on its way to the lower lands or not. Further, the defective sanitary state of Bengal, due to imperfect or interrupted drainage, would apparently quite justify the Government in summarily requiring by law the free surface drainage of the whole country, and in strictly prohibiting irrigation where proper drainage was not carried out simultaneously. This is

Vide Public Works Department No. 2087, dated 20th August 1868. provided for to some extent in the new draft Bill by Colonel Strachey, to which attention may be given in relation to this subject.

18. Until these questions are disposed of, His Excellency in Council cannot attach much importance to the estimate of returns from the proposed works.

19. On the subject of drainage, I am further directed to state that so far as this has to be provided for at the expense of the State, too

much attention cannot be paid to it in designing the canal and its subsidiary works. Wherever the embankments are raised above the level of the surrounding country, drains should be carried continuously along the outer slopes, and the water got rid of by running off into the canal again at a lower level, or into some natural drainage channel.

20. One other point has still to be noticed : The Governor General in Council is quite willing to allow of a fair provision of inspection buildings being included in the estimates, but it is very necessary that nothing in excess of reasonable wants should be provided ; and, in order that the arrangements contemplated by the local Engineers may be properly controlled, full details of all buildings should be furnished. On this point, I am to request the attention of His Honor to the remarks in paragraphs 28 to 30 of the Officiating Inspector General's Note.

21. The provision of suitable escape channels calls for attention.

22. The plans and estimates received with your letter are returned.

Note by Officiating Inspector General of Irrigation,—(31st May 1869.)

It is proposed to make the channel with a capacity equal to the discharge of 1,500 cubic feet per second. A much larger supply is available during the rains, and the question has been raised as to whether the capacity should not be increased to 3,000 cubic feet per second.

2. As irrigation under the Damoodah is as yet untried, and as it impossible to know beforehand to what extent the people will take water, it will probably be admitted that it is desirable to confine operations within a limited scale in the first instance, so long as this can be done without entailing extra expense when any further extension of the system is proved by experience to be necessary. Nothing of course is done by the present arrangements to interfere with the formation of channels on the south bank of the river, and if the designs of the northern channel are so arranged that the supply may be increased, if required at any future time, up to 3,000 cubic feet per second, nothing further is required.

3. The supply now allowed, 1,500 cubic feet per second, will be carried with a depth of 7 feet, and velocity of $2\frac{1}{4}$ feet per second, that is in the upper part of the channel where the fall is 6 inches per mile. This quantity might be increased to 2,000 cubic feet without any sensible alterations of the plans, but if it were to be raised to 3,000 cubic feet, the depth would have to be increased to 10 feet and the velocity to $2\frac{3}{4}$ feet per second, and the gates and masonry work at the heads of the locks, the aqueduct retaining walls and various other works, as also the banks, would have to be made to withstand a depth of 3 feet in excess of what is now provided. The thickness of the masonry works to withstand this extra pressure would have to be increased by about 1 foot, and if this is allowed now, the works may be raised to the required height at any future time at no greater expense than would be incurred if they were raised to the full height at once. The embankments may also of course be raised hereafter in the same way; but, with regard to the masonry falls, it is desirable that some increase of width should be provided.

4. The channel, as now designed; is to have a depth of 7 feet, and a fall of 6 inches per mile for 28 miles. The fall is then to be gradually reduced to 4 inches, 3 inches, and 0 per mile, and the velocity from 2.2' to 1.8', 1.5' and 0 per second. I think 2.25 feet a favorable standard for the mean velocity, if an occasional increase of supply is contemplated; and, considering the advantage of keeping the velocity within moderate limits for the sake of the navigation, I would not advocate any change, especially as, from a great part of the channel being within embankments, the saving effected by increasing the velocity would not be proportional to the reduction in the width of the channel.

5. The arrangement proposed for gradually reducing the slope of the channel and the velocity would lead to an extensive deposit of silt. Colonel Rundall refers to the muddy character of the Damoodah freshes. In paragraph 23 of his Note, he explains that the high embankments along the line of channel are necessary on account of the irregularity of the profile of the ground, but that they would be quickly stanchd, and that the hollows in the bed would also be silted up to a uniform level. But silting would not stop here, and it is

evident that precisely the same result would arise from the channel having any excess of capacity in regard to width, as there would from excess of depth. So that if the upper part of the channel has the hollows in the bed silted up, until the stream has a mean velocity of $2\frac{1}{4}$ feet per second, and then remains permanently free from silt deposits, there must surely be reason to apprehend that in the lower reaches of the canal, where the mean velocity is reduced to 1.8 or 1.5 feet per second, the silting will go on, until, by diminishing the capacity, it should bring the velocity to the standard of that in the upper reach. There is, so far as I know, only one method of preventing injurious silting, and that is to keep up the velocity to the point where irrigation and navigation are to be combined, and from that point onward to have the channel for still water navigation only. In this case, allowing a top width of 75 feet, or a bottom width of 50 feet for navigation, the required velocity of $2\frac{1}{4}$ feet per second would be obtained with a depth of 7 feet, and a fall of $\frac{1}{10000}$ or 6.3 inches per mile, and the resulting discharge would be about 900 cubic feet per second. If there is sufficient land below the 65th mile of channel for utilizing this quantity, this point would be a convenient one for commencing the purely navigation channel; and by a glance at the map it will be seen that a complete quadrant of 25 miles radius is commanded, and as this is equal to an area of 490 square miles, we have at 250 acres per square mile, 122,500 acres available against the computed duty of the water, *viz.*, $900 \times 133 = 119,700$ acres, so that there can be no objection to the arrangement I have suggested as regards irrigation, and from the great advantage it would afford with regard to silting I would recommend it for adoption.

6. The width above mentioned, 50 feet at the sole of the channel, would be the minimum width in the first 65 miles. From the 65th mile upwards it would be gradually increased, and at the head it would be about 100 feet wide; but if the depth is retained the same throughout, the width should always be in proportion to the quantity of water carried.

7. I observe that Colonel Strachey suggests a reduction of the width of the navigable channel to 55 feet at top. I had recommended the same thing for the navigable channels in the Gunduck Project

before I had seen Colonel Strachey's remark ; but I would make an exception in favor of the Damoodah Canal, in consideration of the great importance of the traffic likely to be carried by it. At all events a top width of 75 feet may be allowed where the canal is in embankments, as it will cost no more than a smaller width, excepting for the additional land it would take up ; and in cuttings some saving would be effected by restricting the width to 60 feet at surface, or about 40 feet at bed. Berms may be left along the latter to allow of the width at surface and bed being increased to 75 and 55 feet, respectively, at some future time, if proved by experience to be necessary or desirable.

8. The supply of 1,500 cubic feet per second is considered capable of irrigating 200,000 acres of rice. This is at the rate of 1 cubic foot per second for 133 acres. The lowest rainfall in Burdwan during a period of nine years was 44.4 inches, and the average 60 inches. The allowance of water is probably nearly sufficient, as it would be equivalent to an additional fall of rain of 32 inches on the computed area of irrigation in a period of 180 days, which would give between 65 and 70 inches in all for the six months from June to November. It would, however, be necessary to allow for an extra supply at such times as the rainfall should be unfavorable, and the channels being designed with the banks only 3 feet above the standard supply level, could not carry much more with safety. A long time is likely to elapse, however, before water will be required for so large an area as 200,000 acres, and it will not be necessary to raise the banks higher until the full supply is called for.

9. It may be remarked that the distribution of the above area is not clearly defined in the map, the areas of the plots under the proposed branches being apparently exhibited at 500 acres per square mile, which may approximate to the whole cultivated or culturable area, whereas the land to be irrigated is to be reckoned at half this rate. There is abundance of land under the canal, but it is not clear that the branch channels have been shown in the map, in conformity with the arrangements likely to be carried out in practice. I have no means of checking the estimate for distribution, namely, Rupees 2 per acre, which Colonel Rundall says was found to be the cost in Cuttack, and I think that detailed estimates for the various rajbhas required should be submitted to the Government of India for approval before they are commenced upon.

10. The sufficiency of single locks, 100 feet long, for the large traffic that may be expected, has been questioned. I would recommend that the length be increased to 150 feet, and that the chambers may be widened to 22 feet at the low water line. A convenient size of boat would be about 60 by 10 feet, and would carry 1,000 maunds, or 36 tons. Four such boats could enter the lock at a time, and the lockage, taking the delay in getting boats in and out into account, would not be effected much, if at all, under 20 minutes, and allowing 12 hours each day for loaded boats and 12 hours for returning empty ones, we should have 5,000 tons per diem, or 1,750,000 tons in 350 days, as the total duty of the locks. This may be considered the maximum; for, in practice, boats would not work up to the full standard. But probably 500,000 tons per annum might be conveyed, or more if very large boats were made, as there would then be a saving in the time of lockage.

11. With cheap coal available, one would naturally expect that the aid of steam power would be called in, and this will be provided for by making the locks 150 feet long; but unless steamers can be made to carry freight economically, and not simply to tow other boats, the great number of locks in the cannal (20) would be greatly against their introduction, as the delay in locking would do away with a great part of the gain in time by steaming.

12. The Executive Engineer's estimate for the canal amounts to Rupees 50,24,816, exclusive of establishments, composed of the following items:—

			Rs.
Weir and head-works	..	..	5,33,527
Earth-work, Main Canal	..	..	18,40,238
20 Locks (with Weirs)	..	..	6,12,000
Aqueducts and Culverts	..	..	5,20,041
Bridges	..	..	2,17,410
Distributaries	..	..	4,00,000
Land ..	..	..	4,01,600
Tools and Plant	..	..	2,00,000
House accommodation	..	..	1,00,000
Temporary Dams and Cuttings..	..	..	2,00,000
			<hr/>
			50,24,816
			<hr/>

13. Colonel Rundall is of opinion that the rates allowed by Captain Garnault are unnecessarily high, and he proposes to effect a considerable saving in the earth-work by re-placing part of the heavy embanking allowed for by cuttings, and by altering the position of the locks. He also explains that a further reduction may be effected if the surface width of the cuttings is limited to 75 feet. The saving in all would, according to his calculation, amount to Rupees 4,56,100, of which Rupees 2,00,000 are due to the reduction of the width of the cuttings.

14. This estimate must be regarded as a rough approximation, and it cannot be determined to what extent cuttings can be economically substituted for embankments, without a detailed examination of all the measurements; but it is sufficient to show that the arrangements proposed by Captain Garnault may be revised with advantage, and I would

* I think this a very necessary precaution in a question which involves the saving or spending of 4 or 5 lakhs of Rupees.

not recommend definitive sanction* for the whole project until this point is settled. With regard to the reduction of width mentioned as an alternative arrangement to what has been designed rather than recommended for adoption by Colonel Rundall, I have already given my opinion as to the extent to which it should be carried; but I may repeat that I advocate a reduction in the last 35 miles of channel in embankments to 75 feet, and in cuttings to 60 feet at surface; and for the upper 65 miles, I propose to reduce the width in proportion to the quantity of water to be drawn off for irrigation, from the maximum of 114 feet at surface at the head of the canal, to 75 feet at the 65th mile.

15. Although the Chief Engineer considers the Executive Engineer's estimate unnecessarily high, the Government of Bengal think it is perhaps more prudent to refrain from making any reduction, as prices of materials and labor appear to be steadily rising. This reason may be considered valid for not making any alteration in the Executive Engineer's *rates*, but not so, I think, with regard to *quantities*. The latter should be calculated accurately, at high rates, if necessary, but it is not desirable that a large margin should be left to cover simple inaccuracies, as would be the case if the Government of India were to sanction the whole of the estimates for Rupees 50,24,816, on the

understanding that there *may* be a saving in earth-work of between 4 and 5 lakhs of Rupees.

16. The estimates for the works generally have not been given in sufficient detail.

17. The sum of Rupees 2,00,000 has been provided for tools and plant, which, I think, is not more than is likely to be required, and Rupees 2,00,000 additional are entered for temporary dams and cuttings, and for unforeseen contingencies, such as injuries by untimely and sudden freshes in the working season.

Para. 41, Memorandum.

18. The latter sum is a large addition to the actual estimate for the weir (5½ lakhs), but Colonel Rundall's experience in such matters is likely to prevent his running into great error; and though the Government of India are not called upon to sanction this outlay now, they may be prepared for it when the contingencies, now unforeseen, come into operation.

19. *Weir*.—The design for the weir having been adopted from that for similar works in Cuttack, Colonel Rundall is the most competent person to judge of its sufficiency. It may be concluded, in the absence of information to the contrary, that the bed of the Damoodah at the site selected for the weir is of a similar character to that of other rivers running to the east coast, in which weirs of the same kind have been successfully carried out. The process of construction will be much simpler than in the case of the snow-fed Himalayan river.

20. The under-sluices of the weir are designed on a pattern which is being tried in Orissa. Such experiments should, I think, be encouraged, but without attempting to prejudge the proposed arrangement. As regards the working of the shutters, I would venture to doubt the propriety of having large openings of 50 feet span. The pattern usually adopted in Madras, that is small vents generally 6 feet wide, arched over, was, I imagine, designed with no other object than to allow of their being easily managed by a few Natives; but they have the great advantage of preventing an undue acceleration of the current during the freshes, from the resistance offered by the piers and archwork, and I have always considered them superior, on that account, to the open dams usually designed in the north of India.

21. I think that 3 feet, as a margin for the crest of the embankment round the head-works above the highest known flood, is insufficient for security, and not less than 6 feet should be allowed.

22. Unless the laterite which is to be used for the flooring of the under-sluices and the crest of the dam is of very superior quality, the wear and tear will be considerable.

23. It is observed that a rate of Rs. 50 per 100 is allowed for cut stone for all the works comprised in the project. If this is not more than sufficient for the weir and head-works whereby far the largest proportion of stone will be used, it is likely to be too low for locks and falls in the lower part of the canal, as water carriage will not be available, unless it is intended to adopt the very slow process of finishing off one lock at a time.

24. *Head Sluice*.—Curved flanks, and returns, in rear, would seem to be wanted.

25. The retaining wall of the head lock has a mean thickness of 4 feet 6 inches to a height of 19 feet 6 inches; hardly one-fourth. For another lock, of which the design is given, an average thickness of $5\frac{1}{2}$ feet is allowed for a height of $17\frac{1}{2}$ or $18\frac{1}{2}$ feet. The latter, I should say, is the more correct proportion of the two.

26. *Lock and Weir*.—The wall of the weir is, I think, too thin; the central sluices are made to extend to the base of the wall, that is to the level of the bed of the canal below the drop. This is surely a mistake. It would weaken the wall greatly, and there can be no object in making the sill of the sluices lower than the bed of the canal in the upper reach. It is suggested that the lock and weir channel may be brought closer together, and that the latter may be curved off from the head of the lock.

27. The Chief Engineer has altered the Executive Engineer's designs of the aqueducts. He has added floors to all, and, in one case, has reduced spans of 50 feet to 30 feet. A thickness of arch of 3 feet at crown, as Captain Garnault proposed for a 50 feet arch, would be hardly sufficient to withstand a pressure of upwards of 500 lbs. per square foot. The flanks of the aqueducts, where the masonry work is

joined on to the earthen embankments, are not securely arranged. The arrangements for the aqueducts on the Gunduck project seem superior. Additional masonry work is also required at the entrances of the culverts to prevent flood-water from getting behind the walls.

28. Estimates for the Locks are not furnished. The cost is assumed at Rs. 3,000 per foot of lift inclusive of the attendant weirs, but as the weirs will diminish in size from the head of the canal downwards,

* Captain Garnault at the end of Section VII. of his Report states that the rate per foot of lift has been obtained from estimates Nos. 6 & 10; but these estimates are for aqueducts.

the expense of the two works together will not be at all uniform.* In any case, detailed estimates must be drawn out before the Government can feel satis-

fied that the cost is accurately represented. One of the estimates, headed Falls and Lock at 12 m. 2 f. appears to be for a Fall and a Lock-keeper's house. The amount is Rs. 13,358, of which Rs. 6,457 are for the house. Perhaps the latter may be intended to suit as an inspection bungalow, but the amount is very large, and I can hardly believe that such an expense is contemplated at each of the 20 Locks required for the hundred miles of canal. A sum of Rs. 1,00,000 has been allowed for

Colonel Rundall's memo., para. 40.

bungalows for the Engineers and Subordinates while the works are under construction, but it is not clear if this is for bungalows at the head works only, or for the whole project.

29. At all events I would take the opportunity of observing that on a line of navigable canal, where officers and subordinates will have facilities for moving about by water, and may live *pro tem* in boats, the provision of chokies is not required to the same extent as on some of the canals in the north of India, and as there must already be some inspection bungalows in connection with the Damoodah embankments, I question if any additional buildings of the kind are called for; and of course the Lock-keeper's houses should be mere huts. Temporary sheds may be required at the Locks and other large works to facilitate inspection, while they are in progress, and they could probably be used for the shelter of the Lock establishments after the opening of the canal.

30. As regards house accommodation for the officers and subordinates at the head works, I would recommend that only those should be

of a permanent character which are likely to be used after the works are finished. The others should be mere sheds I think.

31. In none of the estimates is there any provision for baling or pumping. The allowance of 5 per cent is not in practice found more than sufficient to cover ordinary contingencies : a much larger proportion will be required if spring water is encountered in the foundations of the Locks, aqueducts, or other masonry works. I cannot tell whether this is likely or not, as the spring level has not been shown on the sections.

32. Nor is there any allowance for drainage cuts. A great portion of the canal is carried in heavy embankments, higher, it may be added, than is consistent with economy or safety, and the leakage through them would be injurious to the adjacent lands, unless catch-water drains are carried continuously along the outer slopes, and tailed into the canal below the Locks, or into the culverts, which are provided at an average interval of about $1\frac{1}{2}$ miles. Probably no great expense will have to be incurred on this item, as earth for the embankments will be partly obtained from cuts outside ; but there will be various breaks at the cuttings, and the ground being of a very irregular profile, unfavorable for long lines of drain, it seems not unlikely that the number of culverts may have to be increased.

33. With regard to Bridges, ten are provided in addition to those at the Locks, or in all 30, at an average distance of $3\frac{1}{2}$ miles. In the plans of the Locks the bridges are not shown, and those for the weirs give a roadway of 8 feet, which is not enough. The other bridges are not conveniently placed, for example, at 24 m., 4 f., 53 m., $8\frac{1}{2}$ m., 4 f., they are within a mile in each case from a Lock ; there being nothing apparently to prevent the Locks being placed opposite the roads at these points. In three of the reaches there is an interval of 8 miles without any bridge. It will be observed that Colonel Rundall proposes to use ferry boats if more crossings are required, and I conclude that if the Government of Bengal is satisfied with the allowance of bridges, the Government of India will not object to the arrangement. Boats would have to be provided out of the estimates.

34. There is a serious omission in Captain Garnault's estimate for bridges. Nothing whatever is allowed for approaches, though the

roadways will be raised above the present level of the ground to a height ranging from 16 to 28 feet, or to a height of 22 feet on the average. This height will be reduced if Colonel Randall carries out his proposal to reduce the canal embankments; but by the present arrangements at least Rs. 2,000 would have to be added to each estimate for the over-bridges, or Rs. 20,000 in all for the ten allowed.

35. On the whole, although considerable ability has been displayed in the preparation of the designs for many of the works, I consider that the estimates will require careful revision before they can be recommended for the final approval of the Government of India. A comparison should, I think, be made between

Memo. paragraph 12.

the cost of the line, as now designed, and one carried to Trebensee Ghaut, as suggested by Colonel Randall.

36. *Escapes*.—I agree with Colonel Strachey that Escapes should be provided, and one especially at the 65th mile. It is not easy to decide exactly what ought to be done in this respect. During a heavy fall of rain, when no canal water might be required for irrigation, there is the choice of letting the full supply into the canal and passing it out again by escapes, or if it is shut off partially the velocity being diminished both by the reduction of depth and by the reduction of fall required to maintain the navigation, silting would ensue. In the first case there is all the useless wear and tear of masonry falls, and in the other the expense and inconvenience of silt clearances. But in any case escapes are necessary as safety valves, and the extent to which they should be used at ordinary times may be determined by experience.

37. On the subject of Returns it may be said that all calculations with regard to them must be purely conjectural. There can be no doubt that if channel irrigation, combined with proper drainage, were substituted for the system now in force, of irrigation from pools and wells, a great saving of labor would be effected and the yield of the crops would be improved. I do not feel satisfied, however, that the Government of Bengal is right in assuming that the new channels are to introduce irrigation over the whole tract commanded by them in place of no-irrigation, for the rice crops must already be raised by irrigation, and to compare the yield of irrigated and unirrigated crops, and to assume that the difference of value in favor of the former will hold good for the

whole area influenced by the channels is, I think, going too far. It seems to me that to introduce irrigation properly it will first be necessary to get rid of the present Native system. In practice it will not be easy to distribute water to the rice fields, for they have at present a set of jheels or wells connected with them, and these are so inextricably mixed up with bunds and small cuts from the drainage channels that to irrigate on at all a proper system it must be necessary to get rid of them first, otherwise we shall merely send down additional water to impede the already defective drainage of the country.

38. Captain Garnault, in page 9 of his report, describes the plan followed by the Natives, and it may be gathered from his remarks that it is a common practice to throw bunds across the water-course, and he attributes the unhealthiness of the districts around Calcutta to this cause. The surplus water from the lands irrigated by the new channels must find its way into the lowest ground. It will either be used there for lands already partly irrigated, or it may submerge lands which may have already as much water as they can dispose of. It will be very difficult to prove what particular water irrigates a field where there are two sources of supply, and of course when any water does find its way to lands already partly irrigated from wells or drainage courses, the people may say they do not want it. They will moreover oppose the removal of bunds or any interference with existing arrangements, and probably in a court of law they would carry their point on the ground of prescriptive right.

39. From want of local knowledge I can only deal with this subject in the most superficial way, but I think there is sufficient to show that in the low-lying lands in Bengal, where a heavy monsoon lays large tracts of country under water, where there is no proper outlet for it from the natural channels having been tampered with, and where irrigation is now carried on on a system directly the reverse of what it is proposed to introduce, the latter system cannot come into operation with full effect until the old one is destroyed, until the drainages are opened out and improved and all accumulations of rain-water are passed off.

40. How far this can be accomplished without special legislation I am unable to say, but if the zemindar's right to do as he pleases with

any water which passes through his land is upheld, I should say that it would be very difficult to get a proper return from the improvements which Government may carry out.

41. The case is very different from that of rice lands entirely dependent on channel irrigation, as it is in many parts of India, or of ryotwarry lands which may be practically re-assessed every year. Here we have a large extent of rice irrigation already. Suppose that in the Damoodah Districts 25 per cent of the whole cultivation are already irrigated, and that 25 per cent more irrigated by the new channels, is there no probability of the water used for the latter finding its way as surplus to the former, and of its turning partial into complete irrigation without there being any way for the Government to get any profit from it, unless it were to establish a compulsory water-rate? I believe that, in practice, the surplus from the newly-irrigated fields would in times of heavy rainfall, by gravitating towards the lowest lands already swamped, simply do mischief, so that we might have zemindars taking the benefit of the water for nothing in one season, and for suing compensation for damages the next.

42. I think it very desirable that information should be obtained of the progress that has been made in Cuttack in extending irrigation from the Irrigation Company's canals. I have seen nothing on the subject except a report by Major Gulliver, written in November 1867. He mentions that the rains of the preceding season had been favorable, that the country was covered with a magnificent crop, and that while this could be obtained without irrigation, there was little hope that the cultivators, as a body, would use the canal water. Now, if the difference in amount and value of irrigated and unirrigated lands is as much as it is represented to be in the reports on the Damoodah Project, it would clearly be to the advantage of the cultivators to use and pay for the canal water. But if they insist on shutting their eyes to this advantage and go on in their own way, I do not see what right we have to expect a different result from any operations which may be carried out in other parts of Bengal, where the conditions of rainfall are not different to any great extent. I do not wish to say a word in depreciation of

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such undertakings, and I have no doubt in my own mind that irrigation, if combined with an efficient system of drainage, could be used with great advantage. But it is the Bengal zemindar or cultivator who is the real judge in the matter, and if in Orissa they obstinately refuse to take water to any great extent from the canals it is difficult to believe that they will act differently in Burdwan. I do not forget famines, or the necessity of doing all that is possible to prevent them; but famine works are not necessarily to be placed on the same category as re-productive works. The latter are to be carried out by the aid of a special loan, and as the interest on that money must be recovered by Government in one form or another, the primary condition laid down with regard to these works is that they shall succeed in a financial point of view.

43. The computed returns for the Damoodah project are promising enough,—

	<i>Rupces.</i>
200,000 acres rice at Rs. 1-8	3,00,000
64,000 „ cold weather crops at Rs. 3	1,92,000
	<hr/>
	4,92,000
	<hr/>
Navigation—	
200,000 tons of coal at Re. 1	2,00,000
100,000 „ stone, lime, &c., at Re. 1	1,00,000
200,000 „ sundries	1,00,000
	<hr/>
	4,00,000
	<hr/>
Total	8,92,000
Less charges	2,46,000
	<hr/>
Net return	5,46,000
	<hr/>

or 10 per cent. on an outlay of 54 lakhs.

44. The above sum would be required to render the works remunerative if an expenditure of 50 lakhs were to yield no returns for a

period of between seven or eight years, supposing that 5 per cent. for interest and the same amount for maintenance were added, as the capital would have doubled in that time.

45. As above indicated, I look to the experience of the Orissa works as the truest guide to a knowledge of the probable results of the present project. I do not mean to say that any want of success that has attended the works there up to the present time is likely to continue, but if there is any clear prospect of improvement, there must be some cause to which it is to be attributed, or there may be causes at work to prevent any real improvement, and we have then to find out what they are, and whether any special measures can be adopted to remove them.

46. I think that full information on these points will have to be obtained by the Government of India before it can afford to dispense with great caution in dealing with projects for irrigation canals in most parts of Bengal.

From the Government of Bengal, to the Government of India,—
(7th August 1869.)

With reference to your letter No. 234I. dated 29th July, I am directed to ask whether the order therein conveyed to defer the prosecution of the Damoodah Canal Works is intended to extend to the Head Works, the preliminary measures for commencing which are being proceeded with agreeably to the sanction conveyed in your previous letter No. 97I. dated 22nd March 1869.

2. The first step necessary being to obtain the land required for the site of the Head Works, Quarries, and Tramway, a Deputy Collector has been engaged for some weeks on this duty.

3. Permission having been obtained from the proprietors to enter upon the Quarry lands previous to their actual acquisition, a Subordinate of experience and a gang of Quarrymen from Cuttack were engaged to commence the opening of the Laterite Quarries.

4. The line of tramway from them to the river has been marked out, and the earthwork is in course of prosecution. A supply of sleepers

has been procured, and rails collected from the Burrakur Bridge and other works, where they are no longer required, so that the tramway may be completed by the time the water has fallen sufficiently to admit of construction being proceeded with in the river bed.

5. Plans and Estimates have been received and sanctioned for the necessary bungalows for the accommodation of the Executive Engineer, his Assistant, and Subordinates, and they have been commenced, as also the buildings required for the Workshops, an experienced Foreman for which has also been engaged.

6. Indents for a supply of the most necessary tools for Carpenters and Smiths have been sanctioned, as also for a few of the machines absolutely required in the Shops and Quarries for the construction of stone waggons, erection of cranes, &c.; and lastly, arrangements have been made for the supply of materials, such as timber, bamboos, poles, lime-stone, &c., all of which are being gradually collected.

7. As these measures are thus satisfactorily progressing, the Lieutenant-Governor, while fully prepared to give a careful attention to the various points noted in your letter, would respectfully deprecate the stoppage of the Head Works, for the commencement of which these preparations are being made, and he is further encouraged to advocate their prosecution by the permission which the Governor General in Council has given to the line of Canal being marked out, as he gathers therefrom that its general direction is approved, and that it is really the intention of the Government of India to proceed with its construction eventually.

8. The Lieutenant-Governor is advised that, if all preliminary measures are stopped, the loss of another season will be involved before the Head Works themselves can be commenced, and, as he is assured by the Chief Engineer that their prosecution will not interfere with any of the suggested alterations in the Canal, or in the masonry structures connected therewith, the Lieutenant-Governor feels less hesitation in asking that their commencement may not be delayed.

9. With regard to the permission granted to mark out the Canal, the Lieutenant-Governor is informed that, until its dimensions have been finally decided, it will not be possible to define the width of land

necessary to be taken up, and consequently the declaration and other preliminaries necessary for its acquisition cannot be proceeded with.

10. The Lieutenant-Governor observes that the Government of India, though requiring the Estimates to be revised and submitted in greater detail, yet admits that the estimates, as they stand at present, probably give a fair first approximation to the cost of the works. He cannot but regret, therefore, that it has been thought necessary not only to withhold all sanction, but to stop the further prosecution of the works, for he is informed by the Chief Engineer that much might be done during the present season along the line of canal itself, as well as at the Head Works, in the way of collecting materials and other preliminary preparation, and yet in no way interfere with the various alterations which, in the opinion of the Governor General in Council, are necessary.

11. Pending the receipt of a reply to this letter, the Lieutenant-Governor trusts he will not be considered to contravene the orders of the Government of India in not immediately stopping the preliminary measures above described as in progress under the sanction previously conveyed. If it is the intention of the Government of India that they should be stopped, a communication to that effect by telegraph is requested.

From the Government of India, to the Government of Bengal,—
(No. 283I. dated Simla, 18th August 1869.)

In reply to your letter No. 1572I. dated 7th August 1869 regarding the Damoodah Canal Works, I am directed to state that the measures described as having already been taken by the Government of Bengal in the matter appear to the Governor General in Council to be such as were contemplated in the orders communicated in Public Works Department's letter No. 97I. of 22nd March last. The estimates for Bungalows, Workshops, or any other works which have been received by the Government of Bengal should be submitted for sanction at once, and the actual prosecution of the Head Works should not be commenced before the designs and estimates are approved by His Excellency in Council.

2. With reference to the remarks made in paragraph 10 of your letter, I am to state that the Governor General in Council desires that the operations along the line of canal itself may be limited to the collection of materials for the aqueducts near the head, as the positions of the Locks and other works cannot properly be settled until the revised designs are received. Orders have recently been received from the Secretary of State to the effect "that no Irrigation Works to be met by loan are to be undertaken without detailed plans and estimates previously sanctioned" by Her Majesty's Government, and the Government of India has no further option in the matter, even if it was disposed to modify its previous orders, which, however, there appears to be no reason for doing.

3. The Governor General in Council has every hope that the replies to the questions put in Public Works Department's letter No. 234I. of 29th ultimo will be of so satisfactory a character as will enable the Government of India to obtain the authority of the Secretary of State for the commencement of the work at an early date.

From the Government of Bengal, to the Government of India,—
(27th August 1869.)

With reference to your letter No. 234I. dated 29th July, conveying the opinion of His Excellency the Governor General in Council regarding the Damoodah Canal Project "that sanction for the further prosecution of the works must be withheld until more full and satisfactory information than has yet been furnished on various important points is placed before the Government of India," I am directed to express the Lieutenant-Governor's regret that the estimates should have been found wanting in completeness so as to render it necessary for the actual prosecution of the works to be deferred until they can be revised.

2. Pending, however, such revision, there are other points in your letter to which a reply may be intermediately given, and I am desired by the Lieutenant-Governor to offer the following remarks on those points in the respective order in which they occur.

3. Passing over the omission of professional details in the designs and estimates, for the absence of which he believes a satisfactory explanation is afforded in the accompanying Note by the Chief Engineer, the Lieutenant-Governor observes that *one of the reasons which render a revision of the estimates necessary is a desire on the part of the Government of India to enlarge the dimensions of the canal so as to enable it to carry double the volume of water originally proposed.*

4. Though such an enlargement will necessitate an entire re-drafting of the plans of the masonry works, the Lieutenant-Governor is encouraged by it to hope that the eventual sanction of the undertaking will not be withheld, notwithstanding the bearing of the remarks contained in paragraphs 14 to 19 of your letter. The points adverted to in these paragraphs will be referred to again, and meanwhile the necessary orders will be issued for the preparation of revised plans; but the Lieutenant-Governor would be glad to learn that the suggestions of the Chief Engineer as to the mode in which the increased supply of water as well as of increased Lock accommodation for the traffic should be given meet with the approval of the Government of India.

5. As regards the question of Reservoirs, the Lieutenant-Governor trusts that all further consideration of the Canal Project will not be postponed pending the submission of the information now called for in connection with those works, though the Lieutenant-Governor hopes to be able to submit with the revised estimate for the canal certain plans and estimates for Reservoirs which are now under consideration.

6. The suggestions of the Officiating Inspector-General, with reference to the arrangement for combined irrigation and navigation, recommended to the Lieutenant-Governor's attention, shall receive full consideration during the revision of the plans.

7. With reference to the best site for the terminus of the canal, the Lieutenant-Governor is quite ready to adopt the proposal of connecting the canal at first with the Hooghly at Tribenec Ghaut, but he is disposed to agree in the view of the Chief Engineer that the canal should eventually be extended to Calcutta. The selection of Serampore, or rather of Biddabatty, as the first terminus, arose from its being the present dépôt at which the principal part of the coal carried by the Railway is stored.

8. The Lieutenant-Governor has carefully considered the remarks of His Excellency in Council respecting the proposed rates of toll, and he is disposed to think that, under the circumstances of this canal, and for the reasons set forth in the Chief Engineer's memorandum, they are not too high, though, if it be still considered desirable, an exceptional rate in favor of coal might be added.

9. The relative advantages of canal to Railway for mineral traffic, as well as the eventual use of steam-power on the canals, have been discussed at length by the Chief Engineer, whose arguments appear to the Lieutenant-Governor to contain much force.

10. The following paragraphs of your letter Nos. 13 to 19 have caused the Lieutenant-Governor some uneasiness; for, taken in connexion with the opinions advanced by the Officiating Inspector General, to whose Note special attention is invited, they appear to imply a hesitation regarding the desirability of undertaking not only the project under discussion, but Irrigation Works generally in Bengal.

11. The Lieutenant-Governor is quite alive to the importance of the several questions discussed in your letter; but, allowing the fullest weight to them, he is unable, in the light of the sad events which have occurred in these provinces during the last few years, to arrive at any other conclusion than that the works which have been projected are essentially necessary for the protection of the inhabitants of those tracts which they will benefit. It is impossible that the Lieutenant-Governor should not feel strongly on this point; for, again in the present year, severe distress, not stopping very far short of famine, has prevailed, and is still prevailing, in several districts under this Government; and, indeed, at no time since he assumed charge of the Government has there been complete freedom from anxiety as to the condition of the people in some part or another of these provinces, owing to the failure or partial failure of crops from want of water, and consequent high prices of food.

12. The Lieutenant-Governor is not unmindful of the fact that it must be a work of time before the existing habits and prejudices of a people can be overcome and changed; but he is unable to see that the people of Bengal are more bigoted in this respect than those of other provinces. Indeed, as far as contact with European resources and

civilization can effect a change, he believes that the people of Bengal shew a better appreciation of these than most parts of India, and that in the particular case of husbandry they will not be slower than their neighbours to avail themselves of improvements which they are quite capable of judging will be to their advantage.

13. Whether it will be absolutely necessary to resort to such special legislation as is alluded to in paragraphs 16 and 17 of your letter is a question on which the Lieutenant-Governor is not prepared at present to express an opinion; but as regards the particular subject of defective drainage, the Government of India is probably aware that it has already engaged the attention of the Lieutenant-Governor as a sanitary measure; and it may be hoped that it is not likely to prove an obstacle in the way of irrigation, which will, on the contrary, become still more necessary in proportion as drainage schemes are carried out. As suggested, however, in paragraph 15 of your letter, the opinions of the District Officers shall be obtained on this subject, though it will be observed that the question of irrigation has been already referred to them in connection with the category of queries which the Government of India desired should be put to District Officers in connection with all new projects of irrigation, and that their answers have been given in Captain Garnault's report.

Memorandum by Chief Engineer, Bengal, Irrigation Department, on the letter dated 29th July 1869 from the Government of India and on the Note by the Officiating Inspector-General of Irrigation,—(20th August 1869.)

This letter conveys the opinion of the Governor General in Council "that sanction for the further prosecution of the works must be withheld until more full and satisfactory information than has as yet been furnished on various important points is placed before the Government of India." This opinion, it is stated, is formed after a careful consideration of the reports and correspondence on the project, and of the remarks conveyed in the Note by the Officiating Inspector-General of Irrigation.

The objections which are raised both in the letter of the Government of India and in the Inspector-General's Note are of two kinds,—one refers to professional details, the other to general principles.

The first will be considered hereafter in a separate Note, when the revised estimates now called for are submitted. The second may be fitly replied to at once. I will therefore notice the several points, commencing with those contained in the letter.

The first objection is urged in general terms as a want of completeness in the estimates, but as only two items of the estimate are specified as incomplete, I infer that the rest of the estimate is not considered open to the same objection. The first item consists in not having furnished separate and specific designs for each Lock and weir on the canal ; and the second in not having accurately ascertained the cost of the minor channels for the distribution of the water for irrigation.

As regards the first, it certainly did not occur to me that separate designs for each of such works as Locks and weirs would be expected, as all these works are essentially of the same character, and a standard plan designed for the mean lift, or level between the upper and lower water, will afford an approximate idea (where the main dimensions of length and width remain the same) of the contents of the structure per foot of lift, while the mean cost is arrived at by allowing the average rates allowed for the whole line. A standard design, shewing the main essential dimensions of length and width, having been submitted for the approval of the Government of India, I was under the impression that the local Government would be deemed sufficiently competent to judge of the design for each specific locality.

I am not quite sure what is meant by the following remark in Colonel Strachey's letter,—“that the fall according to the arrangement now proposed would so far as can be understood in some cases be inconveniently great,” but conclude, it alludes to the differences of level of 15, 18, and 20 feet proposed to be overcome in these localities. I am not aware myself of any inconvenience attending such an arrangement, which is usually resorted to wherever a sudden alteration of level in the ground occurs ; and, indeed, it is considered rather a convenience than otherwise to be able to place Locks *in flights*, as thereby longer reaches of canal are obtained. Examples of this arrangement will be found in the canals on the Godavery. Orders will now be issued in conformity with the instructions of the Government of India for the preparation of separate designs.

The second objection is expressed as follows :—“ The arrangements for the distribution of the water and the tracts of land which are to be irrigated are only very faintly sketched out, and the cost has not been at all accurately ascertained.” In reply to this, I would beg to point out that the tracts to be irrigated by any system of canals in delta countries is *arbitrarily defined and limited* by the configuration of the ground. The main undulations are clearly discernible on any accurate map, such as the Trigonometrical Atlas Sheets, by the direction of the drainage channels.

When then a main line of canal is taken along the water-shed, as in the case of the Damoodah Canal, the respective tracts that can be irrigated and the direction of the main distribution channels are so clearly defined as to be unmistakeable to any Engineer of practical experience in this matter. The cross levels with which the area in question has been intersected likewise show to what extent such of the tracts is sub-divided by minor drainages, as well as the general slope of the country in the direction of, and transverse to, the intended line of irrigating channel; and if the tract proves to be similar in character with other neighbouring localities where the distribution of water in detail has already been properly carried out, and where the rates for earth-work are similar, it is obvious that the expense of that distribution cannot greatly vary. With the experience of what the actual cost of distribution works in Orissa has been, both at Cuttack and at Midnapore, which is the neighbouring district to Burdwan, it is quite possible to judge that the expenses of distribution under the Damoodah Canal would be somewhat similar.

What that expense is will be gathered from the facts that at Cuttack 11 Distributaries measuring 116 miles have been completed for the Kendraparra Canal as far as the earth-work, head sluices, and other masonry works are concerned. From these channels 80,000 acres can be irrigated. The expenditure has been Rupees 1,14,976, thus making the cost Rupees 990 per mile, or 1.43 Rupees per acre. At Midnapore, Distributaries measuring 61 miles and commanding 45,000 acres have been made at a cost of Rupees 67,858, thus giving a rate of 1,112 Rupees per mile, or Rupees 1.5 per acre. Some further expenditure will be

required in furnishing small distribution pipes to the respective field channels, the cost of which, however, will be but trifling. Further, in practice, it is found that a mile of Distributary may be roughly assumed as required for every square mile of area to be irrigated, but more accurately from 650 to 750 acres. The cost per mile will vary according to the declivity of the country from 1,000 to 1,200 Rupees per mile, thus giving an average rate of about 1.5 Rupees per acre. Thus it will be seen that the estimate of Rupees 2 per acre has not been fixed without good reason, and that the best test of accuracy, that of actual cost under similar circumstances, has been made the ground-work of the estimate. The submission of so minor a detail as that of the Distributaries, for the approval of the Government of India, I certainly did not suppose could be contemplated, much less that it would be thought necessary that all the Distributary channels should be previously surveyed in detail. When the land to be commanded is, as stated above, plainly marked out and limited by the drainage lines, and the cost approximately known from previous experience, the detailed surveys, which would in every case be submitted to the local Government for approval, are best made when the main canal is in course of construction. With reference to the remark that "the precise alignment of the subsidiary channels does not appear to have been considered or determined on," the explanation given above will show that the selection of a line for a main Distributary is not a matter of choice, but is arbitrarily determined by the levels of the ground, and these levels have, as already stated, been taken.

The next point adverted to in Colonel Strachey's letter is the capacity for which the works are to be designed. The simplest and, in my own opinion, the right way in which provision should be made for passing a double supply of water down the canal, should such be eventually determined on, is not to enlarge the existing weir, but to build a second weir of the requisite size on the opposite side of the Lock. So also to provide for increased traffic, it will be better to build an additional Lock rather than enlarge the present design, *first*, because the size is sufficient to accommodate the traffic at the outset; and, *secondly*, because the extra expense is not incurred until there is a certainty of its being remunerative. If necessary for the accommodation of steamers, the second Lock can be made 150 feet in length, though I think vessels

90 feet long by 15 feet beam will carry engines of sufficient power for the traction of cargo boats at a moderate speed. The superior convenience of this arrangement is, that in the event of an accident happening to either weir or Lock the whole supply in the canal need not be stopped, as the duplicate works will of course be available. To increase the supply in the canal itself by increasing the depth only will involve change in the dimensions of the aqueducts, culverts, and height of Lock-walls and gates, but it is a question for consideration whether the works should now be charged with this additional capital outlay.

It does not seem quite clear whether the present project is to be kept in abeyance until the information for Reservoirs now called for can be completely furnished. Taking the views expressed in paragraphs 5, 6, and 7 of Colonel Dickens's letter No. 1821. dated 31st July 1868, in connexion with the information now called for, I conclude the intention of the Government of India is not to postpone the consideration of the Canal Project till that of the Reservoirs is settled, but simply that it is desirable that the information regarding the latter should be supplied shortly, in order to allow of a final decision being arrived at regarding their proving useful and profitable adjuncts to the work or otherwise. The re-consideration of the proposed arrangements for combined Irrigation and Navigation as well as of the suggestion of the Inspector-General on this point will receive attention, and be discussed in another memorandum, together with all the other professional objections which have been urged.

As regards the terminus on the Hooghly there is no objection to making one at Tribenec Ghaut ; indeed, I suggested the advisability of making the connection with the Hooghly there first, but I am still of opinion that the canal should be brought to Calcutta. It is quite true that boats will always have the advantage of the tide from Tribenec, though, during the period of the freshes, or for about four months of the year, the flood tide is of very little help. Having to wait for the tide, moreover, involves a certain amount of delay, which would be avoided were the canal to be available at Calcutta itself. The selection of Serampore or rather Biddabatty was mainly on account of its being the principal depôt where the coal is at present stored, and therefore a fitting place for a temporary terminus. The selection of Tribenec for

the convenience of the Eastern Bengal Railway will, however, as far as the present consumption of coal is concerned, be consulting the interest of only a small portion of the whole coal traffic. From the memorandum marginally noted, which was alluded to in paragraph 49 of my former Note, it will be seen that the coal consumed by the

<i>Consumption of Coal in 1867.</i>		Tons.
East Indian Railway	206,000	
Eastern Bengal Railway	34,000	
Tug Steamers	108,000	
Up-Country Steamers	25,000	
Oriental Gas Company	15,000	
Government Steamers and Docks	11,000	
Factories on shore	93,500	
	<hr/>	
	492,500	
Brick-burners' rubble coal	4,000	
	<hr/>	
	496,500	

Eastern Bengal Railway was only 34,000 tons out of a total consumption in the year 1867 of 496,500 tons. If then the relative consumption by different parties is to be the criterion of the location of the terminus, Calcutta and not Tribenec should manifestly be the place. However, as the quickest way of effecting a junction with the Hooghly, and for the convenience of such coal as will be transported up the Ganges, the line to Tribenec should be made *first*. As pointed out by me in my previous Note, the actual saving in expense will be only the cost of the earth-work and bridges, and probably amount to not more than one lac of Rupees, exclusive of the cost of land, which may be Rupees 50,000 more. In view of the branch to Tribenec being made first, the survey of it has been completed and the plans are ready.

As regards the proposed toll of one Rupee per ton, I do not myself think that it is too high when the great concomitant advantages of being able to deposit the coal at the precise spot or vessel for which it is wanted, without the expense and loss of breaking bulk, is taken into consideration. It is not merely a question of the cost of haulage, or of the differential rates between rail, river, and canal that has to be considered in fixing the toll. The canal by connecting the collieries with the Hooghly gives them the advantage of access to the whole river system of Bengal. The traffic will not be confined to coal moreover, though for that matter, if it be thought advisable, a special rate might be charged for coal. Another circumstance which should also regulate the amount of toll is the length of line to be traversed. When the distance which any material has to be conveyed is *short*, such material can afford to pay a higher toll, than when it is long; for the cost of carriage in the latter case bears a much larger proportion to the intrinsic

value of the article carried. Hence the charges made by vessels for cargo taken long distances are always proportionately less than those which are levied for short distances. A toll of one rupee per ton per 100 miles would bear heavily for goods transported from Benares to Calcutta, and might, when added to the *charge* for transport, be almost prohibitory, as it would add five Rupees to the cost of an article whose intrinsic value in the Calcutta market might not be more than 10 Rupees per ton, while the same toll on the same article transported from Raneegunge would add only one Rupee to that value. I would therefore recommend that the higher rate be levied at the outset, for it will be much easier to lower it than to raise it hereafter.

I do not quite understand in what way the facilities of sending coal to the Hooghly by the River Damoodah has been understated, as the actual cost which the Coal Companies are in the habit of paying for coal transported by that route was given in Captain Garnault's Report.

In comparing the relative advantages of carriage by rail and canal, I did not lose sight of that possessed by the former in being able to transport the coal from the pit's mouth; whereas trans-shipment will, at present at all events, be necessary for that which will be sent by canal, though, if proper arrangements be made, it should eventually be discharged from the waggons at once into the boats; but I consider that that advantage is more than counter-balanced by the ability which the canal secures to deliver the coal at any spot, or on board any vessel in the river without breaking bulk; whereas, by the Railway, it must be unladen at the terminus, where, under present arrangements, it has to be handled afterwards, at least twice before it reaches the place or vessel where it is wanted. That water-carriage can be taken very near to the pit's mouth however, as well as the rail, will have been evident to any one who has visited the "Black Country" in England, where, if I remember rightly, the system of small branch canals, some of them on high levels, is carried to a great extent.

My assertion regarding the incapability of the Railway to carry the coal traffic was with special reference to the demand made upon it by the general traffic of the country. I made that assertion not inadvertently, but advisedly; first, because I spoke of the Railway as *it is*, and

not as it might be, and also of what I had been given to understand had been the experience of the Coal Companies during the previous year; and secondly, because though the carrying powers of a double line, "with a sufficient number of sidings, good management, and, it should have been added, sufficient rolling-stock, may be nearly unlimited," theoretically, yet it is *practically* very far from being so; for on lines where there is large passenger traffic, the slow goods traffic must and does give way, and there is consequently a very decided limit to such traffic. One of the many items included in the term "good management" and absolutely necessary before any intricate system of sidings and crossings can be introduced is the training of efficient and reliable pointsmen, an important class of persons, whom I think it will be admitted it will be difficult to secure in this country, at least for a long time to come.

With respect to the question of whether steam-power will eventually be used or not on this canal, I would submit that though it may as yet be a matter of surmise and depend on many questions now unsettled, yet that present doubts ought not to influence the projection of this canal and similar works so as to make it impossible for a steam-power ever to be used on them hereafter. The rapid strides which India has made in the application of steam of late years make its use on canals before long a matter of certainty, and therefore, rather than contract the width of the navigation canals, as both Colonels Strachey and Anderson seem to think should be done, I am most strongly of opinion that every possible care should be taken to admit of their being made hereafter more capacious than I even contemplated, unless we are indifferent to the reproach of short-sightedness from those who come after us, and of having prevented them from reaping the full benefit which a judicious application of steam-power confers.

If it be determined, as Colonel Anderson states he has recommended, to reduce the width of the canals in the Gunduck Scheme to 55 feet on the surface, and sufficient provision be not made at the same time for their being widened hereafter, I am perfectly certain that it will prove to be a very grave mistake, for there is no comparison between the relative importance of a *single* line like the Damoodah Canal, and of a *system* of canals like those of the Gunduck, which will be

ultimately connected with not only the entire river system of Bengal and the North-Western Provinces, but also with the canals now in progress throughout this part of India. If, however, it be merely intended that a width of 55 feet will suffice for the present, and that the further enlargement of the canals shall be progressive, I fully agree in the principle which entirely accords with my own views. In estimating for the project, however, it was necessary to make provision for the *ultimate* dimensions of the canals in the Gunduck Scheme.

The fact is that up to this time no real attempts have ever been made in India to introduce or organize a regular *system* of Canal Navigation. Beyond the efforts which have been made in the Deltas of the Kistna and Godavery nothing has been accomplished except in isolated localities, and now that attention has been awakened to the subject, it is of the highest importance that whatever is done in the way of Navigable Canals should be so done as to work in with all the existing river systems, and in Bengal especially, to afford every possible opening to the extension of that wonderful traffic which its rivers already convey. But if we adhere to past precedents, instead of profiting by the lessons which they have taught us, and instead of adapting our canals to the use of steam, purposely shut them out therefrom at the present time, it seems almost certain that, what with the progress of the country and the diminishing value of money, it will every year become both more difficult and more costly to procure the land that will be requisite for widening the canals, and an insurmountable obstacle will be created to any improvements being effected hereafter.

The Despatches which have lately been published dwell on the policy of using every means, and turning to account every improvement, by which the State Railways may be made to prove remunerative undertakings. Surely the same policy is not less applicable to the State Water-ways which carry so much larger a proportion of the traffic of the country.

With respect to the sufficiency of the supply for the estimated area of rice crops, I must in this instance beg leave to retain my previous opinion. If anything that supply errs on the side of excess. With regard to the rubbee crops, I am quite open to correction, as my experience does not extend to such crops as wheat, indigo, and so

forth. With reference, however, to the question of returns, and to the points raised in the Officiating Inspector-General's Note, to which especial attention is drawn, I do feel qualified to give an opinion, and trust that what I have to advance on the subject will be accepted, as written not in the mere spirit of controversy, but with the desire to shew that the hesitation which is manifested in the statements made in the papers now under discussion is based not on any points hitherto unknown and newly brought to light, but that similar obstacles have presented themselves on the submission of almost every new project of any magnitude, and that difficulties which seemed insuperable at the outset have in time gradually melted away.

I would begin by observing that I am not aware of the calculations in the present instance being "conjectural" any more than in other projects of a similar character elsewhere. In the Deltas of the Godavary and the Kistna, the subject of returns was just as conjectural from the same point of view, and in the projects of the North-Western Provinces it does not seem to have been any less so. In the Madras Deltas there existed irrigation from tanks and wells to a larger extent than in the tract of country now under discussion, and at the outset there was similar hesitation on the part of the cultivators to abandon the system of cultivation which had been handed down to them from generations, and similar mistrust evidenced as to the certainty and superiority of canal water. It was a long time before the sugar-cane cultivators gave up raising water from wells 20 to 30 feet deep, while the possessors of land under the village tank were considered more fortunate than those who were obliged to irrigate from the canal direct. In the North-Western Provinces the tenacity with which well-cultivation is held to has been often dwelt upon. Adherence to ancient custom and prejudice therefore is not very different in Bengal from what it is in Madras and in the North-Western Provinces, and I cannot see why the following argument should not rather have been used than that which has been adopted. "If ancient systems of agriculture have been gradually abandoned elsewhere, what reason is there for supposing that they will be more obstinately adhered to in Bengal?" Until a proper system of irrigation was introduced into the southern Deltas, the rice fields there also were connected

with jheels and wells, and bunds and small cuts from drainage channels were the means of irrigation in vogue, so much so, that, while the main canals of the Godavery were in course of construction, temporary measures were adopted for throwing water into these very drainages, in order that the irrigation from them might not only not be stopped but might be extended. The facts mentioned in paragraph 38 of the Officiating Inspector-General's Report are not confined to Bengal, and the opposition that may possibly be made to interference with "prescriptive rights" cannot be more strongly combated than it is in Madras, where the "mamool" or "custom" generally regulates the decision in water disputes. The Bengalee Zemindar is doubtless more litigious and better acquainted with what the law can do for him ; whereas a Madras ryot resorts to the cudgel sooner than the Court to settle a disputed point. There is not much difference, if any, between the low-lying lands in Bengal and those of any other Delta. All require equal attention to the improvement of the drainage channels, and, in the present instance, the drainage of the Hooghly and other districts in the neighbourhood of Calcutta is occupying especial attention from the Government as a *distinct* measure, quite independent of whether irrigation be supplied or not. There need be no ground, therefore, for the fear expressed in the Inspector General's Note of the canals only sending down additional water to impede the already defective drainage of the country, for it seems probable that the drainage will be attended to before the irrigation channels can be finished.

With respect, however, to the question of whether the cultivators will adopt a better system of husbandry, or, in other words, prefer a regular to an irregular system of irrigation, the little experience already gained is to the effect that they will do so. The first lands irrigated from the Midnapore Canal were some of the low-lying tract along the lower part of the River Cossye, south of the Trunk Road from the Hooghly to Midnapore. The cultivators of between 3 and 4,000 acres applied to the Executive Engineer for a Distributary for the express purpose of substituting river water for the rain water on which they had hitherto been dependent, and added further that, if the lands of their villages hitherto swamped by the rain could be *drained*, and river water supplied instead, they would sign leases to,

I think, an extent of 10,000 acres. The progress of irrigation in Orissa has been small, not because the cultivators will not use the water, for they will help themselves to it *surreptitiously* whenever they can, but simply because they object to pay for the privilege, and it was a mere question of time as to who shall yield, the cultivators or the Company. The remarks made by Major Gulliver, and quoted by Colonel Anderson, would have been equally applicable to the Godavery or Kistna District in a year of "favourable rains," when to all appearance "magnificent crops" might have been seen covering large tracts of country, but no one will assert now that the cultivators in those districts, who also at first "insisted on shutting their eyes to the advantages" of Canal irrigation, have not grown wiser in their generation. If Major Gulliver had passed through Orissa in September 1865 he would have seen similar crops which a fortnight afterwards perished from drought even after 60 inches of rain had been registered up to that time.

I do not quite understand the distinction which Colonel Anderson seems to draw between famine works and re-productive works. I had always supposed hitherto that the question of the necessity of providing Irrigation Works in Bengal had been finally settled by the experiences of 1865 and 1866, and that the policy which dictated their construction rested not so much on their immediate direct re-productiveness as on the fact that the country could not afford to bear such drains on its resources and such disturbance of its finances as the late famine had caused. The Financial Member of Council who introduced the policy and provided for the first irrigation loan stated publicly, when delivering his Budget speech, words to that effect, adding that he was content to leave it to his "unborn successor" to reap the profits said to result from Irrigation Works, but that meanwhile the necessity of guarding the country against a recurrence of recent calamities *must* be provided for.

The points now adverted to are very similar to those which were called forth ten years ago, when the proposals of the Irrigation Company were first laid before Government. If they are now to be revived, and Irrigation Works in Bengal are to be suspended until they are again settled, I fear we shall be launched into a region of discus-

sion which it will take another decade to decide. The Districts bordering the Rivers Sone and Gunduck and comprised in both North and South Behar have again this year been the scene of very severe scarcity, which, according to the reports of the Civil Revenue Officers, nothing but timely relief measures could have prevented from becoming positive famine, while it must not also be forgotten that an interval of only three years has elapsed since the last was experienced. It seems certain that considerable loss of revenue will result from the extensive tracts affected by the scarcity of the present year. Can then works calculated to save the State such loss in future, and its consequent burden of interest on the revenues, be considered in any other light than as re-productive; and, if so, should their construction be yet matter for hesitation?

Looking at the question from even a purely financial aspect, and apart from the experience of what various provinces of Bengal have passed through in previous years, and what some have suffered during the present year, I trust I may not be considered transgressing the bounds of respect by expressing my own conviction, with reference to the need for caution enjoined in the concluding paragraphs of Colonel Anderson's Note, that, if one lesson of caution has been taught us rather than another, it is *not to defer execution* of the only works which can preserve the country from a recurrence of those visitations which paralyze the main sinews of its strength in periodically destroying its agricultural resources and wealth.

From the Government of Bengal, to the Superintendent of Works,
Damoodah Circle,—(1st September 1869.)

Referring to the correspondence as per margin, copy herewith forwarded, relative to the canal from

Public Works Department's letter
No. 2347, dated 29th July 1869.
Note by the Officiating Inspector-General
of Irrigation dated 31st May 1869.

Raneegunge to the Hooghly, I am directed by the Lieutenant-Governor to transmit, for your information and guidance, the accompanying Memorandum of Instructions by the Chief Engineer for Irrigation, together with the original plans and estimates.

MEMORANDUM.

The Government of India having returned the plans and estimates for the Damoodah Canal for revision, the attention of the Superintendent of the Damoodah Irrigation Works is called to the following points :—

1st,—It is proposed to increase the capacity of the canal so as to enable it to carry 3,000 instead of 1,500 cubic feet per second, and this is to be effected by increasing the depth and not the width.

As, however, such increase is only to take place hereafter and not immediately, no alteration in the height of the banks need be provided for now; but it will be necessary to revise the designs for all the masonry works, so as to admit of the increased depth of 3 feet being given when required.

For this purpose all the side walls of the aqueducts must be strengthened so as to bear the increased pressure arising from an additional depth of 3 feet. The arches of the aqueducts will also have to be increased in thickness, as well as those of the culverts. Careful calculations should be made for each span of arch to bear a weight of 10 feet of water.

The thickness of the chamber walls of the Locks will likewise have to be increased proportionately to the increase of height, while the gates will have to be designed and the quoins to be built for the ultimate height at once. The weirs will have to be altered similarly, or rather the thickness of the front retaining wall and wings, and the width of the cut-stone apron, must be designed for the ultimate height of over-fall. The increased height can be given to the front wall at any time, so that it will not be necessary to make any change in the length of the weir on this account.

In order to discharge the additional volume of water, it will be preferable to build a second weir instead of increasing the dimensions of the existing one, and so with regard to providing increased accommodation for the traffic, a double set of Locks will be more useful than enlarging the size of the single Lock as designed from 100 to 150 feet. As, however, the Government of India has recommended a Lock of

the latter dimension, a plan and estimate should be made for a specimen Lock of that size, with a view to comparing the relative cost of the two designs, in case it may be considered desirable by the Government of India to adhere to the larger size.

The bridges, however, must be designed so as to preserve the full headway ultimately required, and this will involve the raising of the approaches.

With regard to the canal itself, the special attention of the Superintendent is directed to the suggestions made in paragraphs 5 and 6 of the Officiating Inspector-General's Note, and he is directed to prepare a revised section on the principle therein laid down of preserving the fall uniform and reducing the width of the canal, with a view to maintain a uniform velocity. The Inspector-General's recommendation is devised on the grounds that there is such abundance of land commanded by the canal that, instead of distributing the supply at a higher point, it will be better to carry a larger portion to a lower point, *i. e.*, to the 65th mile, and irrigate a larger quantity of land below that point than was originally intended. But there is one important point to be considered with reference to this subject, and that is—where is the water likely to prove most useful, and to be soonest taken?

On this point the Superintendent should institute careful enquiries, and ascertain locally, as far as possible, the want of the tract of country in question in respect of irrigation water.

With reference to the surface width, the sections must be so prepared as to allow of a berm being left, in order that the Canal may be widened eventually to 75 feet, and a comparative estimate prepared shewing what the relative cost of the canal will be for each width specified.

The Government of India has adopted the Inspector-General's observation to the effect that the alignment of Distributary Channels does not appear to have been considered or determined on, and that there is, therefore, some doubt as to the correctness of the estimate in this respect. The Chief Engineer is responsible for that estimate, but the Superintendent should now explain to what extent it will be

possible to convey to the Government of India a more accurate idea of the precise alignment of the Distribution Channels. As the country has been minutely cross-levelled, the Chief Engineer believes the Distribution Channels can be laid down with tolerable accuracy; and as the rate of fall in the country is obtainable from those levels, it should be easy to arrive at a fairly approximate idea of the cost of each main Distributary and the area which will be commanded thereby. The Superintendent should also state what length of time the surveys of the Distributaries in detail is likely to occupy, and what is the earliest possible date on which they could be commenced.

With reference to the remarks in paragraphs 13, 14 and 15 of the Inspector-General's memorandum, the Superintendent will be good enough to re-consider the disposition of the Locks on the original section, and explain, not in general terms but for specific miles, how far a re-distribution of the relative proportion of cuttings and embankments may be improved so as to give a more economical result, and, in drawing the revised sections, his attention should be especially given to the point of so arranging the Locks as to give a minimum cost of each description of work.

The sum of Rupees 2,00,000 entered by the Chief Engineer for temporary dams, &c., must be retained in the estimate, as the Officiating Inspector-General has mistaken the kind of contingencies for which that sum has to provide.

The Superintendent's attention should also be given to the points noted in paragraphs 25, 26, and 27. The remark in paragraph 23, with reference to the estimated cost of cut-stone for the head works being the same as the average rate allowed for the works along the canal, calls for explanation. It had escaped the Chief Engineer's notice that such full rate had been allowed.

Drawings of the houses for the accommodation of the Engineers as well as of Inspection Bungalows must be prepared, and the strictest economy exercised in the latter class of buildings, so that nothing beyond what is absolutely necessary is provided.

An item for baling, as suggested in paragraph 31, should be added to each of the Lock estimates.

The Superintendent's attention is likewise called to paragraph 32 relative to the necessity for providing a greater number of culverts, and whether the Inspector-General's suggestions regarding the drainage cuts to those culverts will have to be carried out.

The Chief Engineer is of opinion that a width of bridge of 8 feet is abundant for the traffic which would occur at the several bye-roads for which bridges have been provided. For the main roads, of course, the usual width has been maintained. Colonel Anderson draws attention to the omission in the estimate of approaches to the bridges. This omission should be rectified, but it appears to the Chief Engineer that there is an error as to the great height of the approaches mentioned in paragraph 34.

With regard to the Reservoirs of the canal, orders had already been issued to the Superintendent to have a survey and estimate made for the alternative terminal section to Tribenec Ghaut. These, which it is believed are ready, should now be submitted.

Lastly, it is suggested that "escapes" should be provided for at certain places on the canal. They are precautionary works, which may be adopted with advantage in most situations, but there is scarcely any great necessity for such works on canals which are protected by regulating works at the head, and into which no drainage is allowed to flow. However, as the Government of India desires to have them provided, sites should be selected where the surface of the water of the canal is just level with the natural surface of the ground, and a masonry wall should be built on at that level, sufficient to discharge say a sudden influx of water caused by the bursting of a shutter in the head sluice, or by a 6-inch fall of rain in 24 hours over such length of the canal as may lie above any escape.

All that is necessary is a platform of masonry provided with wings to prevent the foot of the embankment from being washed away. Probably the best sites for these escapes would be found at the Tumlah, Banka, and at that intermediately between the latter and Tribenec.

In paragraph 6 of the letter the Government of India desires to have the question of the extent to which a cold weather supply of water could be utilized more fully discussed, and observes that from

the information now before the Government it would seem that, in six years out of eight, Reservoirs would probably not be needed. With respect to these questions, the Superintendent should give an analysis of the cold weather volume available in the river for each month during which cold weather or rather spring crops are on the ground, and the probable area on which such might be cultivated, if possibly ascertainable, and the quantity of water which would be required month by month to supplement the available river supply. Such information can at present be only approximately ascertained, it is believed, but, nevertheless, this is the only way in which the subject can be discussed at present. Any reliable information regarding the cost of Reservoirs besides that already submitted by the Superintendent should be also furnished.

Any statistical or other information which the Superintendent may have acquired since the submission of his report on the subjects alluded to in paragraphs 37 to 41 of the Inspector-General's Note should be afforded in such report as the Superintendent may forward with the revised estimates.

From the Government of Bengal, to the Commissioner of the Burdwan Division,—(2nd September 1869.)

With reference to the proposed canal from the Damoodah at Raneegunge to the Hooghly, I am directed to request you will furnish the Lieutenant-Governor with such opinion as your experience of the districts under your charge, and through which the canal passes, has enabled you to form, and that you will further elicit opinions from the Collectors of the districts and any competent private parties, regarding the anticipated beneficial effects or otherwise of the canal, more especially as regards its irrigable properties.

2. In Section 1 of Captain Garnault's Report, the replies of the Collectors of Burdwan and Hooghly are given to the question as to whether irrigation is now practised, and to what extent. The replies of those Officers differ somewhat; and as neither of them treats the subject of irrigation for his district at any length, the Lieutenant-Governor would be glad to receive their views after a further and

careful consideration of the subject, especially in the light of the irregular distribution of the annual rainfall which has been experienced of late years, and of which the present season seems about to afford a somewhat remarkable instance.

3. The attention of the Collector of Burdwan might be drawn to the remarks expressed by Captain Garnault regarding the irrigation practised at present in the district of Burdwan and of the actual facts observed by that Officer.

4. The Government of India has observed in a late communication that "it would be a strong argument in favor of this project if it could be shown that the people could be induced to give up their present defective system, and that irrigation of a superior kind could be immediately afforded them, which being also combined with efficient drainage would probably contribute vastly to the general healthiness of the country."

5. The Lieutenant-Governor is desirous of knowing your own opinion and that of the local Officers, whether it is likely that the cultivators will be ready to substitute for their present system of husbandry an improved method of cultivation; in other words, to exchange their present desultory efforts for an improved system of continuous irrigation when the means are afforded them of doing so. That it may require some time before the change is introduced is, of course, probable, but the Lieutenant-Governor is disposed to think that in this respect the cultivators of Bengal are not more bigoted than those in other parts of India, or slower to appreciate an advantage when fully persuaded of it.

6. The Government of India has expressed a fear that, unless such a change is effected, the supply of irrigation water from the Damoodah may prove absolutely injurious. This must, of course, pre-suppose the absence of any improvement in the drainage of the country; but the substitution of a supply of fresh and fertilizing water from the Damoodah has been so often represented to the Lieutenant-Governor as a measure likely to improve the sanitary condition of the districts affected, that he believes it will be hailed by the people generally as a boon. It seems to stand to reason that, when the

present obstructions to a free and uninterrupted drainage have been removed, the substitution of a stream of running water for the existing stagnant pools will help to remedy the unhealthiness of which it is said the latter have been one of the principal causes.

7. A question, however, has been raised as to whether by interfering with such existing arrangements as are necessary for the system of irrigation as at present carried on, and attempting to introduce another system, difficulties may not be encountered in dealing with proprietary rights with regard to water-supply. The Lieutenant-Governor wishes to be informed whether any such proprietary rights as to water-supply now exist; and, if so, whether there are any such insuperable difficulties as would prevent satisfactory arrangements being made with the proprietors regarding the introduction of a better and more certain supply by means of the Government works. The question of drainage, as you are aware, is already occupying the attention of Government, independently of the introduction of a system of irrigation. This, therefore, should be borne in mind by you when dealing with the subject of this letter, to which I have to add, in conclusion, the Lieutenant-Governor's request that you will give it your earliest attention, and allow as little delay as possible to elapse before forwarding your reply.

8. The correspondence connected with the Damoodah Canal Project having been published in the Supplement to the *Gazette of India* dated 21st August, I am to refer you to that *Gazette* for all such information connected with this scheme as may not have yet reached your Office, and the Lieutenant-Governor will of course be glad to receive any observations, on points other than those indicated in this letter, which the correspondence may suggest to you.

Despatch No. 98 dated 12th October 1869, from the Secretary of State for India, to the Government of India, (communicated by the Government of India on 23rd November 1869).

I have received and considered in Council your Excellency's Despatch, dated July 29th (No. 97), 1869, reporting the sanction of your Government to the immediate commencement of the weir and head-works of the Damoodah Canal.

2. The canal is intended both for navigation and irrigation, and there seems to be every reason to anticipate that it will be useful and remunerative in both respects; but more exact and precise information is necessary, both as regards the extent to which the canal is likely to be used for navigation by the Raneegunge collieries, and the amount of water that will be wanted for irrigation by the cultivators. Until this is furnished in a satisfactory form, you have decided upon confining operations to the prosecution of preliminary measures for commencing the head-works of the canal, on which, however, I trust no heavy expense will be incurred until the project is fully matured.

From the Government of India, to the Government of Bengal,—
(17th January 1870.)

I am directed to acknowledge the receipt of your letter No. 1725I. dated 27th August last, replying to a communication from the Government of India relative to the Damoodah Canal Project, and forwarding a Memorandum by the Chief Engineer, Colonel Rundall, on the same subject.

2. I am first to notice a few points on which some misunderstanding appears to have arisen as to certain remarks of the Inspector-General, and expressions in the Government of India's letter on matters connected with the project.

3. As to the form of the estimates, it is the well known practice of the Department that precise estimates of the actual works to be executed in carrying out any project must be prepared and sanctioned. The plans and estimates sent up in the present case were avowedly incomplete, and though the Chief Engineer may have believed that his arbitrary corrections of the first estimates would give a result sufficiently approximating to what was likely to be the eventual expenditure, the Government of India, while not denying that a fair first approximation to the cost might thus be arrived at, could not accept such an expression of opinion in lieu of the exact calculations which the custom of the Department based on long continued experience requires. The Secretary of State has recently noticed with dissatisfaction that parts of the work have been permitted to be begun before the complete estimates of the whole were matured, showing that Her

Majesty's Government have taken a still more strict view of this question than that taken by the Governor General in Council.

4. As to the designs of the works, the Government of India has no desire to fetter the discretion of the Chief Engineer in submitting what he thinks most suitable. A final judgment can be formed when they are received. What was said was that, so far as could be understood, the falls in some cases seemed likely to be inconveniently great, and a remark was made by the Inspector-General that in the present case he thought a lock of 150 feet in length was preferable to one of 100 feet.

5. Regarding the distributaries, all that was suggested was that this part of the project was too incompletely indicated, and that the evidence given as to the probable cost of the necessary works seemed insufficient to give a satisfactory basis for an estimate. The Governor General in Council does not desire any extreme elaboration of the details of this part of the project, but considers that something more reliable than a simple expression of opinion might be furnished as a foundation for an estimate amounting to £40,000.

6. It was not intended that the further consideration of the project should be delayed till the question of Reservoirs should be decided. If the Reservoirs had formed an essential part of the scheme, financially considered, the Government of India would have been constrained to have waited till the proposals relating to them had been matured. But it was understood that the project does not depend on these works for its success, and that they are looked upon as supplementary, and likely to be Remunerative independently of the canal, which also will give sufficient returns without the Reservoirs. Therefore the Government of India merely stated that it would be very desirable to have a final decision come to as to these works, so that the whole project might be complete.

7. Further, I am to remark that the intentions of the Governor General in Council, with respect to the matters discussed in paragraphs 14 to 19 of my letter of the 29th July last, seem not to have been made clear. The Government of India is not more backward than the Government of Bengal in feeling the necessity for providing as early as

possible any practicable means for protecting the population of Western Bengal from the effects of drought which have been felt with special severity during the last few years. The evidence of the readiness of the Governor General in Council to act up to this conviction is sufficiently given, if it be sought for, by the whole course of its policy since 1864. It was on the urgent representations of the Government of India that the works of the Orissa Company were taken over at their full original cost, with the express purpose of extending their usefulness to the utmost, in the shortest time possible. When the same Company showed its inability to carry out the Sone works, the Government of India at once accepted the duty with a considerable pecuniary sacrifice, and those works are now actually being prosecuted. In the case of the present project, the Government of India, believing that it was in the main sound, permitted preparations to be made for the commencement of the head-works, the completion of which will regulate the time when the canal can come into operation, in anticipation of the formal sanction of the complete project and estimate. In no part of India has the Governor General in Council hesitated to act as he has acted in Bengal. The needful funds are freely supplied for the preparation of projects that promise success, and for the prosecution of works the designs and estimates for which have been approved.

8. But the Governor General in Council has other duties. It is one of the first of these duties to watch the condition of the public finances, and to guard scrupulously against the possibility of embarrassment arising from the creation of permanent charges on the revenues, to meet which a corresponding source of income shall not have been certainly provided. The application of large sums of borrowed money to Public Works creates charges of this character, and it is a paramount duty imposed on the Government of India to satisfy itself before permitting such outlay that the return from the works to be executed may reasonably be expected to be sufficient to cover all charges from maintenance and interest. The Governor General in Council, in the discharge of this highly responsible trust, has deemed it to be necessary to make further enquiries regarding the Damoodah Canal Project, its probable powers of accomplishing what it purports to do, and the prospects of the income to be derived from it. This, and this only, is the

intention of the paragraphs of the letter of the Government of India to which reference has been above made.

9. His Excellency the Governor General in Council feels confident that the Government of Bengal will accept the distinct declaration of the Government of India that it desires to facilitate to the utmost the prosecution of the great irrigation works in progress or contemplated in various parts of Bengal. But His Excellency in Council must at the same time appeal to His Honor the Lieutenant-Governor to recognize the weighty responsibilities placed upon the Government of India in relation to the expenditure of the vast sums required for the completion of the many great engineering operations now in progress in all parts of India, and to believe that this Government faithfully endeavours to perform the duties imposed upon it by its financial responsibilities. The Governor General in Council will therefore look forward to receiving the cordial co-operation of the Government of Bengal and its Officers in meeting the reasonable wishes of the Government of India in respect to the supply of any information considered necessary, both as to the engineering features of projects brought forward, and their probable financial results. In this manner only can be secured the end which is alike aimed at by both Governments, and by every well-wisher of this part of Her Majesty's kingdom.

10. With these remarks, His Excellency the Governor General in Council would commend to the early and careful attention of the Government of Bengal the consideration of the system under which the financial interests of the State may best be guarded in relation to the irrigation works to be undertaken in Bengal. The Government of India is not disposed to accept as satisfactory an arrangement under which the general revenues of the country shall be made liable to meet all charges arising from these works for an indefinite period of time. Some plan should be devised by which such a result might be avoided, and the burden be placed at all events to some extent on the land for the improvement of the productive power of which the works are essentially designed. Until some such method of meeting the necessary annual outlay due to the construction of new irrigation works is matured, and the danger of these undertakings adding permanently to the charges against the revenues is so guarded against, the Govern-

ment of India must continue to hesitate as to their prosecution, until very complete evidence is adduced of the prudence of permitting it in each case. It is believed that there will be no serious practical difficulty in devising a system of local rating that should accomplish what is desired; and of the equity and necessity of such a measure the Governor General in Council has no doubt. Whether the provisions of the Canal Bill for Northern India now before the Legislative Council of the Governor General would be applicable in Bengal, His Honor the Lieutenant-Governor will be the best judge, but something analogous to the procedure described in Sections 49 to 62 seems likely to give the security that would be suitable and sufficient, and that would justify the Government of India in recommending for sanction to the Secretary of State any project the general characteristics of which were otherwise satisfactory.

From the Government of Bengal, to the Government of India,—(7th April 1870.)

With reference to your letter No. 2347. dated 29th July 1869, and in continuation of my letter No. 1725 dated 27th August,

* No. 68 of 1869-70 of this Office.
† No. 125 ditto ditto.

I am desired to re-submit the accompanying plans* and estimates† for the Damoodah Canal, revised agreeably to the instructions conveyed by the Governor General in Council, and to the suggestions of the Officiating Inspector-General of Irrigation, and to express the Lieutenant-Governor's hope that, the deficiencies complained of previously having been rectified, the estimates will now be deemed sufficiently complete to admit of their being forwarded to the Secretary of State for sanction.

2. A Note by the Chief Engineer reviews in detail the alterations which have been made, and therefore it is only necessary to state here briefly that these alterations consist of—

First,—Enlargement of the masonry works so as to admit of the canal carrying eventually double the volume of water originally proposed, or 3,000 instead of only 1,500 cubic feet per second.

Secondly,—Re-arranging the slope of the canal according to Colonel Anderson's suggestion so as to carry 900 cubic feet of water for the irrigation of a proportionate area of land at the terminus, instead of distributing it as originally intended.

Thirdly,—Placing the terminus of the canal at Tribence Ghaut, instead of carrying it to Bidabatty.

Fourthly,—Increasing the dimensions of the masonry structures and supplying the omissions noted by the Inspector-General.

The estimates as revised amount, after correction, to Rupees 51,49,700, instead of Rupees 50,24,816, for although the canal is 12 miles shorter, the additions to the masonry works more than compensate for the saving in earthwork.

3. The Lieutenant-Governor has caused this alteration of the terminus for the canal to be made, in deference to the opinion expressed by His Excellency the Governor General in Council, but the Lieutenant-Governor believes that the continuation of the canal to Calcutta will be required eventually, and it is certain that the longer it is delayed the more expensive will the purchase of the necessary land be found. As far as present requirements are concerned, the proximity of the terminus to Chogda does not seem to be a matter of importance; for if, as is urged, "boats can drop down the Hooghly to Calcutta with the tide with perfect ease and safety," they could for the same reason reach Chogda from Biddabatty or Calcutta on the flood tide with equal ease and safety. The Lieutenant-Governor believes that any present money saving in the earthwork will be nearly, if not quite, balanced by the additional cost which will have to be paid for the land hereafter when the extension of the canal to Calcutta shall be found to be a necessity.

4. As regards the distribution of the water, and the remark to the effect that the tracts of land selected for irrigation have been very faintly sketched out, the Lieutenant-Governor is led to hope that the explanation given by the Chief Engineer has sufficed to satisfy the Governor General in Council that the subject had been both carefully considered and determined on, as in your letter No. 167. dated 17th January last

it is stated that "the Governor General in Council does not desire any 'extreme elaboration of the details of this part of the project.'" The Superintendent of Works has now further explained that all the essential preliminary steps were taken for determining the land to be irrigated and the direction in which the distributary channels would run. The Lieutenant-Governor trusts, therefore, that the explanation which has been given will be accepted by the Governor General in Council, for the Superintendent of Works has stated that to make detailed surveys, estimates, and plans for all the proposed Distributaries would delay the submission of the project for another season.

5. With respect to the question of the Reservoirs, as it is observed in the first part of paragraph 6 of your letter No. 167. above quoted that it was "not intended that the further consideration of the project should be delayed till the question of Reservoirs should be decided," the Lieutenant-Governor understands that this question is not to interfere with the submission of the canal project. He does not therefore now forward the Reservoir projects which have been submitted by the Superintendent of Works, as the Chief Engineer states that he is not satisfied with them in their present state.

6. As regards the proposed arrangements for combined Irrigation and Navigation in the Main Canal, and the Inspector-General's suggestions to which special attention is invited in the 7th paragraph of your letter, it will be observed that the estimates have all been revised in accordance with those suggestions, but the Lieutenant-Governor must express his own confidence in the views of the Chief Engineer, whose long experience on Navigation Works enables him to speak with authority on the subject, and whose opinion, therefore, the Lieutenant-Governor trusts will be allowed full weight before a final decision is adopted as to the dimensions of canals of navigation in Bengal.

7. No one who has traversed the provinces under this Government can fail to appreciate the immense advantages conferred on Bengal by the magnificent lines of water communication which it possesses. And the Lieutenant-Governor feels that every project which has for its object the extension of this communication to localities where it has not before existed, and which serves to connect those localities with the general system of navigable rivers and canals throughout Bengal, is invested with great importance, and that canals for navigation should be designed

not only with reference to the necessities or conveniences of the immediate neighbourhood affected by them, but that they should be regarded as an integral portion of the vast system with which they are incorporated and be dealt with accordingly. The Lieutenant-Governor therefore entirely concurs in the view that in designing canals, for Bengal at all events, "it will be impolitic not to profit by the experience gained in other countries, and so avoid mistakes which they now find themselves obliged to correct at very considerable expense."

8. The Lieutenant-Governor has already in my previous letter expressed his opinion as regards the proposed rate of toll to the effect that it is not too high; but added that if considered desirable an exceptional rate might be made in favor of coal.

9. In connection with this subject the Governor General in Council desired that the probable cost of haulage should be ascertained, and that an accurate comparison between the Railway and Canal rates should be instituted. Captain Garnault has discussed this subject at length in one Section of his report, in which he shows that the relative rate of conveyance by rail and canal between Raneegunge and the Hooghly is Rupees 4-8-0 and Rupees 2-2-0 per ton, or, inclusive of toll, a saving of one-half the cost in favor of the canal, even if the same complement of crew be allowed to each boat in the canal as on the river. But the Lieutenant-Governor is disposed to think, as has been before observed, that the cost of haulage, or of the differential rates between railway, river and canal are not so much main points for consideration in fixing the rate of toll as the actual distance to which goods have to be transported and the proportion which the cost of carriage bears to the value of the articles transported.

10. The Lieutenant-Governor proceeds to notice paragraphs 14 to 19 of your letter, and, with reference to the special points raised therein, would request the careful perusal of the accompanying letter from the

Commissioner of Burdwan,* forwarding reports from the Collectors of Hooghly and Burdwan respectively.

* No. 1T. dated 3rd January 1869.

11. The Commissioner not only observes that in the opinion of the local Officers, supported by those of the Zemindars and Ryots,

"very great benefits may be confidently anticipated from the canal," but adds "that there is no such thing as irrigation in its scientific and systematic sense," and therefore no "present defective system" (such as is apprehended in paragraph 14 of your letter,) "which the people are to be induced to give up."

12. The Commissioner is likewise of opinion "that if all the irrigable land within reach of the Canal and its Distributaries is made liable by law to a certain rate for the use of the water, the cultivators will gladly avail themselves of the certainty then given them, and the only dispute will be between them and the landowners for their share in the profit."

13. Further, there does not seem to that Officer any sufficient reason to apprehend the consequence feared in paragraph 15 of your letter, or "that there will be any such escape of surplus water from the canal into the irrigable land as to interfere with or increase the difficulty of the general drainage of the country."

14. As regards the proprietary rights referred to in your next paragraph, the Commissioner affirms that no such rights as to water-supply exist in the district in question, except on the Rivers Selye and Dalkissur, with neither of which the present canal is in any way connected. The bunds to which Captain Garnault referred in his Report are said to be confined to the beds of the Saraswuttee and other old channels of rivers which have now silted up, and are the same as those which have been reported on by Mr. Adley in connection with the drainage of the Hooghly district. The Commissioner is of opinion, and the Lieutenant-Governor agrees with him, "that it is most undesirable that the question of this canal should be entangled with the questions of drainage and sanitary improvements," inasmuch as the latter require in the present instance to be taken up separately and are already it may be hoped in course of being provided for.

15. The decided opinion which the Commissioner has expressed regarding the benefits to be derived from this project, added to the details which are furnished by the Collectors of the districts of Hooghly and Burdwan, will, the Lieutenant-Governor hopes, be considered by the Governor General in Council sufficiently assuring as to the soundness

of the basis on which the estimate of returns previously submitted was founded. r

16. The Lieutenant-Governor desires now to turn to your letter No. 16I. dated 17th January, written in reply to my letter No. 1725I. dated 27th August last. The Lieutenant-Governor trusts that the papers which accompany this letter will satisfy the Governor General in Council that co-operation on the part of this Government and its Officers is not wanting in meeting the wishes of the Government of India in respect to the supply of information for which that Government has called both as to the engineering features of the project and its probable financial results.

17. Referring to the 9th paragraph of the letter, I am to say that the Lieutenant-Governor very thankfully accepts "the distinct declaration of the Government of India, that it desires to facilitate to "the utmost the prosecution of the great irrigation works in progress or "contemplated in various parts of Bengal." Still the Lieutenant-Governor must confess that he finds expressions in the following paragraph (10) which tend to diminish the sense of security, which the words above quoted are otherwise calculated to give. As long as the Government of India feels that it must hesitate as to the prosecution of irrigation works, unless special measures of taxation are resorted to in order to guard against "the danger of these undertakings," adding permanently "to the charges against the revenues," the Lieutenant-Governor cannot but be apprehensive that practical effect to new projects of irrigation for these provinces will be long delayed.

18. For it appears to the Lieutenant-Governor that if it is considered imperative to devise a plan by which the general revenues of the country shall be relieved from the liability of meeting the charges arising from the construction of irrigation works, a doubt is presupposed either as to the remunerativeness or the necessity of these works; and, if so, it seems to the Lieutenant-Governor questionable how far the Government would be justified in requiring the people to contribute compulsorily to such works.

19. The assurance conveyed in paragraph 7 of your letter, however, shows that the Government of India fully recognizes the *necessity*

“ for providing, as early as possible, any practicable means for protecting the population of Western Bengal from the effects of drought which have been felt with special severity during the last few years,” and therefore, if there be any doubt whatever regarding the works, it must refer only to their remunerative character.

20. Setting aside the fact of the losses from which Government is saved by the prevention of scarcity and famine, it appears to the Lieutenant-Governor that the question of the remunerativeness or otherwise of these works must depend mainly on the manner in which they are projected, and that it will be exactly proportionate to the degree in which comprehensiveness of design is combined with economy in cost and maintenance.

21. The Lieutenant-Governor ventures to think that the projects which have been submitted by this Government have not failed in either of those particulars ; indeed the criticism of the Government of India and the recommendation of its professional advisers have tended rather to arbitrarily contract the one and to question the sufficiency of the other.

22. But when a doubt of so grave a kind is advanced, as whether the State should undertake irrigation works unless under a positive guarantee of a certain, full and early return upon the outlay, the Lieutenant-Governor cannot but recall to mind the discussions which took place between the years 1863 and 1865, when he had the honor of being a Member of the Governor General's Council, regarding the policy of irrigation works being constructed by the State, and the general admission then made that when designed on proper principles they had never proved to be a burden on the revenues of the country, but the reverse. It was this in fact, in addition to the strongest considerations of humanity, which led the Government of India to urge upon the Secretary of State the duty of providing works of irrigation for the preservation of the country in the following words :—

“ The history of the last famine in Upper India is still fresh enough in the memories of every one to render superfluous any general comments on the appalling character of a season of drought over a large area. In like manner, we believe that the luminous

“ report of the late Colonel Baird Smith sufficiently demonstrates, without any further remarks on our part, the real power of systematic irrigation to amend the worst consequences of such a season of drought, and proves that against such visitations there is in truth no other security possible ; of all other things, and among them improved communications, acting only as feeble palliatives. It will be a day of the greatest promise for the future well-being of India, when the Government shall take the first decisive step towards the gradual, but systematic introduction of irrigation works into every district now liable to occasional seasons of drought, and shall thereby lay the foundation of a new order of things, under which the sound and material progress of the community will no longer be liable to be suddenly arrested and thrown back indefinitely, as is now the case, and as must ever continue to be the case, so long as the country is left without the safeguard of a sufficient supply of artificial irrigation to support the people and the cattle in a season of drought.”

23. The enclosures of the despatch from which the above words are taken contained strong expressions by the Governor General and by others of a conviction that the general prosecution of irrigation works was a great measure of public policy, and that moreover it was one that was almost certain to be directly remunerative, irrespectively of the immense advantages to the country indirectly proceeding from it. The following remarks found in No. 9 of the enclosures of the despatch, from the pen of an officer whose advice then as now had much weight with the Government in the decision of such questions may be cited as very accurately expressing the sentiments which were at that time held by all who interested themselves in the great and important question of constructing irrigation works in India :—

“ I may here repeat” (Colonel Strachey writes) “ that my own distinct conviction is, that if the Government can carry out these works themselves they should do so. But rather than go without irrigation works, I would make the best bargain possible with private companies. I can, however, see no real difficulty in the way of Government going fairly into these operations. There could be no practical difficulty as to funds, as it is pretty certain that the *direct* return would very soon cover the interest on the money sunk. The Government could raise

“ 20 millions for such purposes with the greatest ease, should it be requisite. The expenditure would be spread over many years, and the supply of the funds would cause no sensible disturbance of the money market, nor discredit the Government. The Government has thought it right to raise 60 millions for railways in a very awkward manner, reserving to itself no power of profitting by the investment. By investing a far smaller sum in irrigation works, the effect of which must be to secure the physical comfort of a large portion of the population of India, in a manner that cannot be attained in any other way, inasmuch as it will secure a certain and plentiful supply of food, notwithstanding the vicissitudes of the seasons, which bring famines as a natural and necessary sequel of the ordinary action of the laws of the climate, an object may assuredly be gained, which, to say the least of it, is as well worthy the attention of the Government as the provision of rapid and easy means of locomotion or transport of produce. Comparing railways with irrigation works, the moral and political inducements to undertake the latter appear to me much the greater; while the financial objections are much smaller, as money sunk in irrigation works could not under the most ordinary management lead to pecuniary loss, and most probably would give an actual direct increase of revenue besides paying interest.”

24. Similar sentiments were again expressed in a later despatch from the Governor General in Council to the Secretary of State in the following terms :—

“ In conclusion, we would express our hope that, after such further consideration and emendation as these proposals may receive from Her Majesty’s Government, they will be found to afford a safe foundation on which to commence a systematic development of irrigation works in all parts of India on an effective scale; and that a provision will thus before long be made for the requirements of the entire country in respect to artificial irrigation, no less successful and no less worthy of an enlightened Government, than that made in respect to the means of communication by the adoption of the policy originated by Lord Dalhousie for the construction of railways. The increase in the prosperity of the agricultural population and of the quantity of agricultural produce which must certainly follow the extension of irrigation

“ works will give a very powerful stimulus to the traffic on the railways ; while the increased facilities of transport will largely extend the markets to which such produce can profitably be sent. The combination of these causes cannot fail to lead to an improved condition of the finances, in part due to the increased wealth of the country, and in part to the reduction of the demands on the State to meet the railway guaranteed interest ; and we shall look forward with much confidence to the results of the hearty adoption of a policy which shall provide for the energetic prosecution of irrigation works within the limits of proper prudence, combined with the gradual completion and extension of the system of railways, the main outlines of which have already been so satisfactorily fixed.”

25. It was under the influence of views and opinions such as these that the local Governments were ultimately, in the early part of 1867, called upon by the Government of India to submit proposals for works of irrigation, and if therefore the Lieutenant-Governor may have seemed somewhat slow in accepting the change of view which has more lately been enforced, and if he has expressed some disappointment and regret at the change, he trusts that this will be attributed to the influence on his mind naturally produced by the broad views which were so ably advocated a few years ago,—views to which the Lieutenant-Governor himself adheres,—and to his great apprehension lest the more recent view, which deprives the works of their imperial character by requiring each work to be locally guaranteed, should have the effect of seriously postponing the prosecution of irrigation works.

Note by Chief Engineer.

The information called for by the Government of India in Colonel Strachey's letter No. 234I. dated 29th July last, in connexion with the Damoodah Canal Project, having been received by this Government, the several professional and other points to which attention was directed in that letter, and which were necessarily left unnoticed in my previous memorandum, may now be discussed.

2. I then remarked that the objections which were raised both in the letter from the Government of India and Inspector-General's Note

were of two kinds, one referring to professional details, the other to general principles; with reference to certain objections of the second kind, it was desired that the opinion of the District Officers might be taken as to whether, unless a great change were effected in the present system of husbandry, the pouring of the water of the Damoodah over these districts might not prove absolutely injurious.

3. The attention of the Commissioner of Burdwan was, therefore, immediately directed to the subject, and that Officer has now submitted the opinions of the Collectors of Burdwan and Hooghly, together with his own, on the several questions raised by the Government of India in paragraphs 13 to 18 of Colonel Strachey's letter.

4. Instructions were likewise at the same time issued to the Superintendent of Works to revise the estimates according to the various suggestions made by the Inspector-General of Irrigation. Captain Garnault has re-submitted the plans and estimates, together with a report, affording explanation on the various alterations which have now been made in the designs.

5. Two main alterations were suggested by the Government of India which materially affect the original design. One is that of planning the works so as to admit of future expansion, and render the canal capable of carrying double the supply, or 3,000 instead of 1,500 cubic feet per second; and the other that of maintaining a uniform slope throughout the canal, and reducing the sectional area in the lower reaches, instead of maintaining a certain minimum section, and adapting the slope thereto corresponding to the gradually diminishing volume to be conveyed. The Governor General in Council likewise directed that the lower section of the canal might be modified, so that Tribenee Ghaut might be the terminus. A further suggestion was added by the Inspector-General to alter the distribution of the water required for irrigation.

6. The estimates and plans as now re-submitted have been altered in accordance with those directions,—

1st,—A fresh alignment of the canal from the 72nd mile to the Hooghly at Tribenee Ghaut has been surveyed.

2nd,—The masonry works have been altered and enlarged, so as to enable the canal to carry double the supply of water when found to be necessary. As the increased supply on the plan proposed is to be obtained by an increase of depth, not of width, it is necessary to add to the dimensions of all the Locks and weirs, in order to make them of the requisite strength, consequent on the additional weight of water to which they will hereafter be exposed. As it will not be possible to add to the height of the Lock-gates afterwards, and as it would be a useless expense to substitute an entirely new set at each Lock, the full height of gate has to be provided for at once, and the masonry in the counterforts designed accordingly. Additional thickness has also been given to the Lock-walls as suggested by the Inspector-General, and these two alterations have increased the mass of masonry in the Lock by about one-third, and raised the average cost per foot of lift from Rupees 3,000 to Rupees 4,000.

7. In my former memorandum I observed that, instead of enlarging the dimensions of the Locks and weirs with a view to provide for the discharge of the double volume of water, it would be preferable to have a duplicate set of Locks and weirs on the canal, as then much of the additional expense would not be incurred until there was a prospect of its proving remunerative, and the traffic would be much more facilitated by a system of double Locks, whereby the upward and downward vessels would be accommodated separately, than by having only a single lock of larger dimensions. The advantage of this arrangement is so obvious that I instructed the Superintendent of Works to provide accordingly, but at the same time to frame an approximate estimate for the 150 feet Lock in case the Government of India should prefer adhering to the Inspector-General's recommendation of having only a single Lock of larger capacity.

8. A further advantage of this arrangement is that the additional Locks and weirs can be constructed without closing the canal and interfering with the traffic, a serious matter when once that traffic has assumed important dimensions. It is, however, a more costly arrangement, inasmuch as to build a second set of Locks will, at the

present estimated rates, cost somewhat under 7 lacs, while to build a single Lock of the larger dimensions, according to Captain Garnault's estimate, will add only 2 lacs to the present estimate. The question is whether the advantage to be gained is commensurate with the larger outlay. I am of opinion that it will be so more particularly as that outlay will not be incurred till it is really wanted.

9. The alterations in the aqueducts, necessary in order to carry the increased supply, have also been provided, as well as two escapes, one at the 12th mile, and the other at the 49½ mile. The two will admit of a discharge of 1,500 cubic feet per second.

10. The bridges have likewise been raised so as to preserve the same relative amount of head-way after the water in the canal has been raised the additional 3 feet.

11. As regards giving the canal-bed a uniform slope with a view to reduce the deposition of silt to a minimum, I consider myself that it is a point of far less importance than that of determining the localities to which the supply of water for irrigation shall be led. The deposition of silt is a difficulty which has always to be encountered in a greater or less degree in every canal project, but it is one which may be measured by the cost necessary for removing the silt, and should not be allowed to interfere with other more important features of a project. In the present instance the question appears to me to be not whether because there is abundance of land to which water can be led at the lower end of the canal that, therefore, a different regime of slope may be adopted, but whether the water is more needed or can be more usefully employed at the upper or lower end. The facts stated by the Revenue Officers lead to the inference that irrigation is more imperatively needed in Burdwan than in Hooghly, and that it will be productive of more useful effect generally in the upper than in the lower portion, at least as far as the main crop of the country is concerned; and, for that reason, I think it would be preferable to adhere to the canal as originally designed. Captain Garnault has given a rough calculation of the quantity of silt that may possibly be deposited in the canal,

and the cost of its removal, which would not be 1 per cent on the capital cost of the works; and on the data which he has assumed he is probably not far wrong in stating that his estimate is high, but he errs in supposing that the cost of removal would be lessened by the use of steam-dredging. I am well aware of Colonel Anderson's views regarding the difficulty of the disposal of silt, but my own experience has not led me to attach the same importance to the matter, neither have I found the removal of silt deposit in canals such as this attended with much practical difficulty, or with any inordinate expense.

12. The reduction of width on the lower reaches of the canal is, as I remarked before, a point which I cannot but strongly deprecate. All the experience obtained in European countries and in America goes to show that the repeated enlargement of the canals in order to increase the facilities of navigation has been continually found a matter of necessity, and insufficient width, as well as depth, has hitherto proved one of the great obstacles to an economical employment of steam power. The width of 55 feet, stated in paragraph 3 of Colonel Anderson's Note to have been suggested by Colonel Strachey, would be quite insufficient to allow two of the large cargo boats in common use in the rivers of Bengal passing one another when laden to a depth of 5 feet. The Coal Companies will, of course, find it to their interest to use the largest boats which the locks can pass. Colonel Anderson recommends that the width in the cuttings be reduced at first to 60 feet at surface and 40 feet at the bed, to be eventually widened to 75 and 55 feet, if proved by subsequent experience to be necessary or desirable.

13. With reference to this subject, I would quote from a pamphlet which I have lately read, entitled "Water communication between the Mississippi and the lakes," containing a memorial to the Congress of the United States on the improvement of the navigation of the Wisconsin and Fir Rivers. This pamphlet was printed only last year, and amongst other matter contains the following particulars:—

1st,—The length of the enlarged Erie Canal is 350 miles.

2nd,—On the enlarged Erie Canal there are 71 locks 110 feet long by 18 feet wide, or one in 5 miles.

3rd,—On the proposed Wisconsin River improvement there will be 38 Locks 160 feet long by 35 feet wide.

4th,—The depth of the Erie Canal is nominally 7, but practically, 6 feet.

5th,—The bottom of the Erie Canal is narrow and the Locks small, permitting the passage of only narrow boats, which for the most part are made sharp at the bottom to avoid friction. The "Improvement" and the Locks upon the Improvement will permit boats which are flat-bottomed, and 50 per cent longer, and 100 per cent wider, than the boats upon the Erie Canal.

6th,—The motive power on the canal is horse-power, and on the Improvement steam. The movement of freight on the former is 1 and $1\frac{1}{2}$ miles per hour, and on the latter from 5 to 7.

7th,—Of three plans proposed by the Officer engaged in this Improvement, the last consisted of a canal 118 miles long, 70 feet wide at bottom and 80 feet at top. Locks 160 by 35 feet. Total Lock-lift 175 feet. Sides of canal in cuts paved to allow the use of steam boats. The estimated cost of this canal was somewhat less than 94 lacs of Rupees.

14. I have quoted the above extracts with reference to the proposal for reducing the widths of navigation canals, and to the doubts expressed both in Colonel Anderson's Note and in Colonel Strachey's letter regarding the introduction of steam power as showing the opinions which are held at the present time by the country in which inland navigation has been pre-eminently developed, and whose circumstances are in every way more nearly similar to that of India than any other.

15. Whatever decision then may be pronounced on the question of the dimensions of the Damoodah and other canals in Bengal for the

present, it is certain that experience in other countries where canal navigation has been most largely developed and is most appreciated, has proved the necessity of enlarging, rather than reducing, the width of navigable canals. Is it politic, then, when designing canals for navigation in India to ignore the lessons which that experience teaches and not rather be careful to avoid the mistakes which those countries are now finding themselves obliged to correct at a very considerable expense? So far, then, from contracting the width of navigable canals, it will at least be prudent that sufficient land should be taken up at the outset to provide a bottom width of at least 70 feet on all main lines of navigation.

16. Amongst other remarks upon various items in the estimates, it is observed in paragraph 17 of Colonel Anderson's Note that the sum of Rupees 2,00,000 added by me to Captain Garnault's original estimate to provide for temporary dams and cuttings and for unforeseen contingencies is large; and it is added, "though the Government of India" "are not called upon to sanction this outlay now, they may be prepared "for it when the contingencies, now unforeseen, come into operation." The erection of temporary dams, the excavation through the inequalities of the sand banks, the construction of the tramway across the river's bed and its removal at the beginning and end of each working season, form under any circumstances a necessary part of the work; and as, when accidents occur from sudden freshes, (to which the Dammoodah is peculiarly liable), while a weir is under construction, the Engineer must have the power of remedying them at once without incurring the delay of a reference to Government; experience in the construction of large weirs has shown the absolute necessity of providing accordingly. This item, therefore, I trust will not be excluded from the estimates.

17. As regards the design of under-sluices, I would remark it is precisely because the pattern hitherto adopted in Madras does not admit a sufficient acceleration of the current that a new design was sought for as a remedy for the evil which has injured the navigation on the upper side of the various dams in the south.

18. With reference to raising the crest of the embankment 6 feet above the highest flood level, the utility of doing so is not quite apparent as long as the crest of the wing walls and parapets of the sluices are made only 3 feet above that level, but the additional height can be given when the work is carried out. The reason why "laterite" has been provided in preference to other material for the sluice floors and crest of dam is because experience on the Orissa Works had already proved its superiority in resisting the wearing action of the sand and water which takes place during the freshes.

19. The Return-walls to the head sluice will be added as suggested. The thickness of all the Lock-walls has, as before mentioned, been increased to the proportions recommended. The central sluice in the Weir-wall, adverted to in paragraph 26, was incorrectly shewn in the drawing, but I prefer retaining the arrangement for the weir channel, and do not think the space between it and the Lock should be diminished. Detailed estimates for each description of Lock have now been submitted by Captain Garnault. As before remarked, this alteration, together with the additional height of gates and quoins which had been ordered, has increased the mass of masonry in the whole structure by nearly one-third, and so raised the cost from Rupees 3,000 to Rupees 4,000 per foot of lift.

20. As regards dwellings and inspection buildings, I think Captain Garnault has not provided more than are necessary for the Officers who will be engaged in supervising the construction, and who will hereafter have likewise to look after the maintenance of the works. As rent is to be taken from the occupants of the one, the outlay will not be unproductive, while, as regards the other, Captain Garnault's remarks as to the necessity of providing adequate shelter during the period of construction are reasonable. As shewn by him, there is but one Inspection Bungalow in connection with the Damoodah embankment that could be at all utilized for the canal works. Should, however, it be considered necessary to provide a less permanent structure, the Inspection Bungalows may be reduced in cost by being built of less durable material; but I question whether any real economy will be secured thereby in a

locality where such violent storms and cyclones prevail, and where thatched buildings are liable to be totally destroyed. Even after the canal is finished, it will be necessary to have some intermediate buildings at which the Officers in charge of the canals can halt for a few days, and these should of course be permanent structures.

21. With regard to the accommodation for the Engineers and Subordinate Officers while engaged in supervising the construction of the Head Works, but which may not be subsequently required, I conclude it cannot be seriously contemplated that Officers and their families should be consigned to "mere sheds," simply because they happen to be engaged on works where their services are not likely to be required permanently, more especially as, whatever the quality or description of the building provided may be, a proportionate rent is to be demanded from every occupant.

22. With reference to the provision for "drainage;" as the canal along the greater portion of its length runs on the highest portion of the country, the drainage to be provided for is very small. It is quite true that the embankments in many places are higher than desirable; but, had it been possible to have avoided these embankments, they would not have been so designed. Where then it is necessary to pass the drainage under the canal, provision has been made accordingly, but in many cases the water will run off equally on either side, and not require to be carried across the line of canal itself.

23. As the bridges provided at the Locks and weirs serve, for the most part, the purpose of mere accommodation bridges for the passage of cattle and villagers, a width of 8 feet seemed abundant; but, on a line of road where regular traffic has to be provided for, the usual width has been given.

The omission in the estimate of the item of approaches to the bridges has now been rectified. Two escapes have likewise been added, but such works are not essential in a canal which receives no water

beyond that which enters by the head sluices, and where the irrigation distributaries can, on emergencies, be used to carry off surplus water to the natural drainages.

24. As respects the construction of "Reservoirs" in connection with this project, the Government of India has, in a subsequent letter, stated that "it was not intended that the further consideration of the "project should be delayed till the question of Reservoirs should be decided." Projects have been submitted by the Superintendent of Works providing for the storage of nearly 8,000 millions of cubic feet of water at an aggregate cost of 16 lakhs of Rupees, but I do not myself feel fully satisfied with the details, and therefore, as they are not essentially connected with the Canal Project, I do not recommend the submission of the plans in their present form.

25. Regarding the "Distributaries," I endeavoured to explain in my former memorandum that the estimate was based on the results of previous experience in adjoining localities, but the fact was likewise stated in the first instance. The Government of India has since observed that it "does not desire any extreme elaboration of the details of "this part of the project," but at the same time "considers something "more reliable than a simple expression of opinion might be furnished "as a foundation for an estimate amounting to £40,000." I am at a loss to know what, short of an elaboration of details, can be more reliable than a reference to previous experience in adjoining localities under precisely similar conditions, or on what sounder basis a general estimate of cost could be framed. As explained by Captain Garnault, the distributaries were marked out according to the cross levels with which the country had been intersected, while the portions of country selected for irrigation were those which, in his opinion as well as in my own, were most in need of it, and where the water would be most appreciated. As much of Captain Garnault's time has been spent in these districts, his opinion on the subject is entitled to weight; and I should, therefore, prefer adhering to the distribution originally proposed, rather than adjust the Main Canal in the proportions recommended in the Officiating Inspector-General's Note, with a view to carrying a larger body of water for the irrigation of land at its terminus.

26. A comparison of the estimate, as revised and re-cast as above described, with those formerly submitted shows as follows :—

	Former Estimate.	Revised Estimate.	Increase.	Decrease.
	Rs.	Rs.	Rs.	Rs.
Weir and Head Works ...	5,33,527	5,37,600	4,073	...
Earth-work, Main Canal...	18,40,238	14,14,800	...	4,25,438
20 Locks with 15 Weirs...	6,12,000	9,57,800	3,45,800	...
Aqueducts and Culverts...	5,20,041	7,48,100	2,28,059	...
Bridges ...	2,17,410	49,000	...	1,68,410
Distributaries ...	4,00,000	4,00,000	...	...
Land ...	4,01,600	4 01,600	...	...
Tools and Plant ...	2,00,000	2,00,000	...	...
Buildings, including Work-shops, Bungalows, &c...	1,00,000	99,800	...	200
Contingencies such as temporary dams, excavations, tramway from quarries and in river bed, &c., &c. ...	2,00,000	2,00,000	...	...
Baling at Locks, Aqueducts, Culverts, &c. ...	...	1,00,000	1,00,000	...
Escapes ...	...	20,000	20,000	...
Ferry Boats...	...	21,000	21,000	..
Total ...	50,24,816	51,49,700	7,18,932	5,94,018

27. The revised estimate is thus somewhat in excess of the original estimate, though the canal is 12 miles shorter; the saving in earth-work is more than counter-balanced by the extra expense in the masonry works caused by the extra strength requisite for the increased depth which doubling the supply will entail. When it has become evident that such supply can be utilized, additional outlay will have to be incurred in raising the embankments 3 feet, in finishing the Locks and weirs to the full height, in excavating the additional distributary channels, and in the purchase of the land for the latter; all these must be taken into consideration before calculating the increased returns which will be obtained from the double supply of water for irrigation; but if the demand

for it is such as to justify the additional outlay, the returns will be in greater proportion than the expenditure. As Captain Garnault has omitted to include the cost of the Work-shops in his buildings, as well as of the tramway from the Quarries to the river, and of ferry boats, which will probably be intermediately required, these have been added to his estimates.

28. It now remains to notice those questions raised in the same Note which, in paragraph 14 of Colonel Strachey's letter, the Government of India remarks "will have to be carefully considered and replied to," and on which this Government is desired to submit the opinions of the District Officers. Those opinions will be found stated *in extenso* in the letter from the Commissioner of Burdwan, and its enclosed reports from the Collectors of Burdwan and Hooghly.

29. The Commissioner observes shortly that, in the opinion of the Collectors, "very great benefits may be confidently anticipated from "the irrigable properties of the projected Damoodah Canal, and that "this opinion appears to be supported by all the zemindars and ryots "who have been consulted by these Officers."

"That there is no such thing as irrigation in its scientific and systematic sense, and that, therefore, there is no present defective system "of irrigation which the people are to be induced to give up; that the "defect with which it is necessary to deal is rather to be found in the "irregular distribution of the annual rainfall, a defect which it is the "express object of the canal to remedy." With respect to the supposed difficulties in "dealing with proprietary rights with regard to water-supply," adverted to in paragraph 16 of Colonel Strachey's letter, the Commissioner observes "that it may be safely affirmed that the only recognized proprietary rights of water-supply are those arising from the "erection of a few barriers across the beds of the Rivers Darkissor and Selye." With neither of them does the Damoodah Canal interfere at all.

The Commissioner further "thinks it most undesirable that the "question of the canal should be entangled with the question of drainage and sanitary improvements." He observes "that the canal will "stand or fall by its own merits; its construction will confer a very "great benefit on a portion of two of the richest, and hitherto, most

“neglected, districts of Bengal, and it will certainly be a profitable investment of money, provided that the works are well and skilfully executed.”

30. The reports of the Collectors of Hooghly and Burdwan are full of interesting details and treat the subject exhaustively as regards the lands and crops for which water will be most valued in their respective districts. In Hooghly it appears that the principal rice crop is grown over the lowest lands on which water accumulates, and that they, therefore, would in his opinion not require artificial irrigation, except for a few days in the months of October and November after the rains have ceased, when a seasonable supply will in years of scarcity save the whole crop from destruction.

But on the higher lands locally known as “Sona,” from which the highest rents are demanded, “artificial irrigation is indispensable.” As regards the probability of the ryots taking advantage of the improved means of irrigation, the Collector of Hooghly is of opinion that, for the better class of land, “the use of water for irrigation is only limited by the supply, while the rate mentioned by Captain Garnault, Rupees 3 per acre (not beegah), is certainly not too high.” The Collector of Burdwan observes that the important point to which he directed his attention primarily was to ascertain whether the difference in fertility between two classes of “Sali,” or low rice-growing lands, (which constitute $\frac{3}{4}$ of the whole district,) arose from difference of soil or difference of level only. That he found it was the latter circumstance that influenced the classification of the lands, those lands being termed “first class” which are capable of retaining the greatest amount of water.

The Collector further remarks that the results of his enquiries show “what an inestimable boon the canal water will bestow upon the ryots of that district,” and he adds in paragraph 10 of his report, “from the many ryots with whom I have spoken on the subject, between this (Burdwan) and Raneegunge, I can say that, excepting the very poor and least intelligent classes, the ryots themselves are fully alive to the benefits they will derive, and, with few exceptions, are quite willing to pay for these benefits.”

31. All the points on which the Government of India desired information are so fully discussed in these reports that it does not seem

necessary to extract here more than the general opinion which, as expressed above, is entertained by the local Revenue Officers regarding the Project.

Report by CAPTAIN GARNAULT on the Damoodah and Hooghly Canal Project,—(dated 12th October 1869.)

In re-submitting the estimates for the Damoodah and Hooghly Canal, which have been revised in accordance with the instructions contained in Government of India's letter No. 234I. of 29th July 1869, and in the Inspector-General's and Chief Engineer's Notes, I will notice all the points adverted to as briefly as possible. The estimates have, I think, been prepared in almost sufficient detail to explain themselves.

SECTION I.—*Distribution of water from the Canal.*

The Officiating Inspector-General of Irrigation in his Note re-
marks that “ it is not clear

Distribution of water from the Canal.

“ that the branch channels

“ have been shown on the map

“ in conformity with the arrangements likely to be carried out in
“ practice,” and in the 4th paragraph of the Government of India's letter No. 234I. of 29th July 1869, it is stated “ that arrangements for the distribution of the water and the tracts of land which are to be irrigated are only very faintly sketched out, and the cost has not been at all accurately ascertained.” The distributaries were marked on the map sheet No. I, according to the levels that had been taken across the country to determine the line of the Main Canal, and were as nearly as possible in the direction of the lines I considered they would eventually take : they certainly have not been surveyed and levelled in detail, and I considered that it would have been premature to have done so when the question of the canal being constructed at all was quite an open one : the surveys cannot be commenced till December, and if the construction of the canal is delayed till the estimates for the distributaries are complete, another working season will be lost.

Even had I received notice previous to March that the canal would have been carried out, I should have arranged for the survey of some of them at least.

I note that the canal is to be so designed that it may be eventually able to carry 3,000 cubic feet per second, instead of 1,500 as originally intended; this will not in any way alter the arrangement I originally made for the distribution of water, and all the distributaries, except Nos. 10, 11, 12, will, for the 1,500 feet supply, follow the same direction I first proposed, but with a diminished capacity, because 900 cubic feet will be taken as far as the 66th mile. From the 66th mile to the terminus at the Koontee Nuddee the canal will be still and for navigation only. I have, however, altered the section of the Main Canal according to paragraphs 4, 5, 6, 7, and 14 of Colonel Anderson's Note.

From the following Table it will be seen how I propose to distribute the smaller supply, *viz.*, 1,500 cubic feet, if Colonel Anderson's proposed arrangement of taking 900 cubic feet to the 66th mile is to be adhered to :—

Number of Distributary.	Mileage of Canal where it takes off.	Area commanded. Square miles.	Area for irrigation. Acres.	Discharge. Cubic feet per second.	CHANNEL.	REMARKS.
					Length. Miles.	
1	17½	3½	875	7	5.20	
2	20	5	1,250	10	4	
3	24	20	5,000	40	10	
4	28	32	8,000	60	18.40	
5	28	50	12,500	95	20	
6	33	25	6,250	50	12.8	
7	33	80	20,000	150	26	
8	44	18	4,500	34	8.4	
9	49	70	17,500	130	20	
10	66	250	60,000	450		
11	66	} 250	60,000	450		
12	...					

The Main Channel will according to this distribution be as follows :—

From 1st to 28th mile the dimensions will be

Surface width	=	114 feet.
Bottom „	=	86 „
Depth	=	7 „
Fall per mile	=	6 inches.

This will give a mean velocity of 2·19 feet and discharge of about 1,500 cubic feet per second.

From the 28th to 33rd mile the canal will be as follows :—

Surface width	=	98 feet.
Bottom „	=	70 „
Depth	=	7 „
Fall per mile	=	6 inches.

This will give a mean velocity of 2·16 feet and a discharge of about 1,270 cubic feet per second.

From the 33rd to 49th mile the canal will have the following dimensions :—

Top width	=	84 feet.
Bottom „	=	56 „
Depth	=	7 „
Fall per mile	=	6 inches.

This will give a mean velocity of 2·12 feet and a discharge of 1,050 cubic feet per second.

From the 49th to the 66th mile the canal will have—

Top width	=	78 feet.
Bottom „	=	50 „
Depth	=	7 „
Fall per mile	=	6 inches.

This will give a mean velocity of 2·10 feet and a discharge of 940 cubic feet per second.

From the 66th mile the canal will be still, and will have a surface width of 60 feet in cuttings and 75 feet in embankments; in the former case the bottom width will be 32, and in the latter 47; the depth in both cases remaining the same, *viz.*, 7 feet; but berms will

be left of sufficient width in cuttings, so that the surface width may eventually be increased to 75 feet.

It now remains to show how I purpose distributing the extra supply of 1,500 cubic feet. I propose extending No. 5 Distributary from Oargram, passing Munglekote, to Cutwa ; there is over 90,000 acres irrigable, and I propose making this distributary carry eventually 760 instead of 95 cubic feet as at present, and it should also be made navigable, as it would then open up a tract of country of which the communications, in the rains especially, are now very imperfect : this takes away 670 of the 1,500, and the remaining 830 I would carry on to the 66th mile, making it available for the whole tract of country lying south of the canal between the Damoodah and Hooghly Rivers, extending to the Oolobarbaria Canal : this area alone is about 900 square miles. One branch should, I think, go to Calcutta following the original alignment of the canal as far as Biddabatty, the other skirting the Damoodah.

I cannot help thinking that the canal as originally designed was preferable to the canal as modified in accordance with the suggestions of Colonel Anderson.

The canal commands an area far in excess of what is able to be irrigated ; it is therefore an object to be able to carry the water to the country where it has the readiest sale : it is impossible now to say with exactness in what part water would be most valued, although, generally speaking, I should consider in the western part of the country commanded, as the slope of the country being greater, a greater portion of the rainfall is drained off, and the rainfall itself is less : still in the lower portion of the country commanded by the canal the cultivation of garden produce for the Calcutta market is steadily increasing, and this is a species of cultivation which can afford to pay much more for water than ordinary field cereals.

As originally designed, the water could be distributed either in the higher or lower parts of the country, and in both cases a good section was available for navigation, the advantages of which cannot be over-estimated, taking into account the large traffic that there is likely to be on the Damoodah Canal and the almost certain use of steam-power.

Colonel Anderson's reasons for the alteration are to do away with silt : our difficulties in this respect we can estimate tolerably accurately : from observations I made last year, when the river stood 13 feet on Kaneegeunge gauge, I found that the silt by volume was 1 in 590 ; the amount of silt, therefore, coming into the canal in the volume of 1,500 cubic feet per second, supposing the river stood 13 feet on the gauge for four months in the year, would be about 30,000,000 cubic feet. Supposing one-half of this passes into the fields by the distributaries, the amount deposited in the first 40 miles would be about 9 inches in depth, and would cost to remove about Rupees 40,000 (and with a steam dredger much less). There is nothing in this to cause alarm, more especially as my estimate is a very high one : the proportion of silt is due to a depth of 13 feet in the river, and this does not occur for more than one month in the year, whereas I have taken it for four months.

SECTION II.—*Reservoirs.*

In reply to the 6th paragraph of the Secretary to Government of India's No. 2347. of 29th July 1869, I have to remark that the question of Reservoirs had no connexion whatever with the Damoodah Canal Project (this the Inspector-General himself, Colonel Strachey, also admitted in his Note on the Reservoir system) ; and that at the time when the investigations for the Reservoir Project were commenced there was no thought of a canal from the Damoodah beyond suggestions which had been thrown out on the subject by different Officers from time to time. The East India Irrigation Company, I believe, purposed prospecting the possibilities of a canal, but beyond a few levels, afterwards found to be worthless, nothing was done. As there would seem to exist some confusion regarding the Reservoir Project, it may be as well to give a brief summary of its history.

In 1852 a very able Note was written by Mr. Ricketts *à propos* of some enquiry connected with the embankments, in which he alluded to the embankments of the Damoodah as follows :—

“ These embankments are each year breached somewhere or other. Not even the Engineers employed have supposed that the embankments afforded protection to the country. It never has been considered

“probable that the whole would stand even for one season. The state of matters is immediately disclosed by the manner in which all concerned spoke of breaches in the embankments. One might suppose that the embankments were made in order to be breached. The Engineers spoke of miles of breaches without shame. In this Department success appears to have been always regarded as hopeless.” In this Note reference was made to a proposition by Lieutenant Beadle, then Acting Secretary to the Military Board, for abandoning the embankments on the right bank, in order to relieve the left bank embankments and render the more important interests on that side, *viz.*, the town of Burdwan, the Grand Trunk Road, and the East Indian Railway, safe from floods: it was recommended that levels and surveys should be taken for the purpose of ascertaining the efficacy of this plan, which I may here mention was preferred to all other proposals by Major Baker, Colonel Garstin, and many other Officers of high position at the time, not perhaps because of the advantage of the plan *per se*, but because of the more weighty objections attaching to all the other schemes.

The whole of the surveys and levels when completed were made over to Captain C. H. Dickens, Assistant Secretary, Military Board, and he went very completely into the whole matter and discussed all the different proposals for protecting the country on either bank of the Damoodah. Captain Dickens observed that “no permanent or satisfactory improvement of the Damoodah so as to secure the country from floods was possible by confining the river between embankments on their existing site or retired at a greater distance, or by new channels; that there were three other modes of remedying the evil,—1st, lengthening the course of the river; 2nd, by forming rapids or weirs to reduce the declivity of the intermediate spaces; and 3rdly, the construction of Reservoirs.”

The two former he pronounced as utterly impracticable from their cost, and regarding the third, he thought that, though probably Reservoir sites could be found, the practicability of the scheme depended on the possibility of getting the water used for irrigation and paid for by cultivators; he therefore recommended Lieutenant Beadle’s plans for adoption, and 20 miles of embankment on the right bank were eventually removed: the result was that the left bank has been ever since

totally free from inundation ; but a large area on right bank has been annually flooded and put out of cultivation, the ryots have been living in a state of insecurity, often during floods on trees and on the tops of their houses, and on one occasion to my knowledge loss of life has occurred. Of course the clamour against the removal has been great, and numberless petitions have been presented to Government asking for compensation or for a remedy. Several Officers have been sent to inspect the right bank to try and ascertain the amount of damage occasioned by the free spill of the floods over it ; but save establishing the fact that a large area of land has been permanently put out of cultivation nothing further has been elicited. The question is a difficult one, as, although it is quite certain that many individual interests have suffered, it is not certain that the whole area has not gained, that is to say, that it is not certain that the income derived from the produce of the whole land on account of the heavier produce on lands fertilized by the Damoodah deposits is not as great now as before the embankments were removed.

I was deputed to survey the inundated land in 1862 and to make a comparison, if possible, between its area and state then and what they were before the embankments were removed. I made this comparison as accurately as possible with information I was able to obtain ; but at the same time recommended that a thorough investigation be made of the river to its source, with the view of finding sites for Reservoirs. The Lieutenant-Governor consented to this investigation being made, and wrote as follows :—

“ The Lieutenant-Governor is not unmindful of the fact that a certain extent of country in the immediate vicinity of the breaches that have occurred has been injured, and that a sense of insecurity still prevails among the ryots from the uncertainty of the action of the river on its bank. His Honor is therefore of opinion that some practical measure should be devised to utilize the flood-waters of the Damoodah, to give confidence to the ryots, and, if possible, to reclaim the land which is now uncultivated.”

In 1864 I submitted a report on four very suitable sites for Reservoirs ; the investigation was continued by Lieutenant Heywood, who found other very favourable sites, and we have now reliable information that more than sufficient favourable sites exist in the higher reaches to

store up all the surplus water of the Damoodah which the channel is unable to carry off: it will thus be seen that the Reservoir Project, so far from being investigated in connexion with the Canal Project, was in reality investigated in order to save from inundation some 100 square miles of country which is periodically inundated on account of the removal of the embankments, for the maintenance of which the owners of the land pay an annual sum to Government.

I wish now to refer to the remarks made on the Reservoir scheme by Colonel Strachey, the Inspector-General of Irrigation, in his Note forwarded with Government of India's No. 182I. of 31st July 1868. Colonel Strachey doubts the practicability of subduing floods by Reservoirs, because he is not satisfied that they can be kept from filling up. I made some experiments last year with the water of the Damoodah, and found that it contained 1 in 590 of solid matter by volume: this would make the Reservoirs silt up in 59 years if filled ten times in a season, (they probably would not be filled five times); perhaps in a shorter time, owing to larger obstacles being rolled down than sand. The silting difficulty has been experienced in all countries in which Reservoirs have been made, but remedial measures have been applied, and there is no reason why similar measures or others which experience has since brought forth should not be applied to these.

The remedies suggested by Colonel Strachey are,—modifying the declivities of the bed by dams or contractions, and in the lower reaches opening out the channels into the Hooghly; the former remedy was one which was pronounced utterly impracticable on account of cost some 15 years ago by Captain Dickens; probably it would now cost double the amount that it was then estimated to cost, and the further fact that the amount thus expended would be entirely unremunerative, except in protecting the lands from inundation (even if successful), is enough to show, I think, that the scheme is not likely to be entertained at the present time. With regard to the second remedy, a proposal was made about 1852 or 1853 by natives, who offered to pay for it, for cutting a canal from Selalpore (the point where the Damoodah turns to the south) to the Hooghly, but it was opposed by Colonel Garstin, who thus writes on the subject:—

“ I perfectly agree with Major Baker that it would be dangerous
“ to admit the water of the Damoodah into the Hooghly, and my

“ reason for opposing the cutting of the canal from Selalpoore direct to the Hooghly (proposed by the natives who offered to pay for it) was that the sands brought down by that river would be deposited in the Hooghly and destroy the Port of Calcutta. That such would be the probable effect of admitting the waters of the Damoodah into the Hooghly, either above or below Calcutta, is more than probable ; for, judging by the effects of letting the Ganges into the Bhaugiruttee at Sootie, and the increased quantity of sand brought down by the Adjai in consequence of the clearance of the Jungle Mehals, similar results, though in a much greater degree, would follow the admission of the Damoodah.

“ History tells us that 100 years ago Admiral Watson took a 64-gun brig up to Chandernagore (with difficulty it is true, but he did it) ; now a small brig could not get up, for a large sand bank has been formed opposite to Chandernagore, another near Barrackpore, and others in other parts. A similar deposit now covering with silt has been formed opposite Shalimar and the Bishop’s College, and in various other parts of the river changes have taken place of late years owing to the sands now brought down and deposited in the Hooghly in greater quantities than formerly.

“ I admit that the James and Mary is formed by the collision of the waters of the Hooghly and Roopnarain ; the former, however, greatly assisted by the Damoodah in the rains, when it brings sand with it, and forcing the current of the Hooghly to the left bank, instead of allowing it to go fairly down its whole channel, and, aided by the projecting left bank, making the opposition of the rivers more direct and causing a great back-water between the Damoodah and Roopnarain under the right bank.”

Colonel Baker also writes,—“ All plans are to be deprecated that involve a risk of throwing a considerable portion of the Damoodah waters into the Hooghly at any other point than that where they now discharge themselves.

“ The silt swept forward by the uniform downward stream of the Damoodah would drop at once and form shoals in the feebler current of the Hooghly, where the alteration of the tides neutralizes the scouring action.”

With regard to the cost of the scheme, there are only two natural channels by which Damoodah water could be diverted to the Hooghly to be of any use, *viz.*, the Banka to the west of Burdwan, and the Kana to the east. Any channel opened out lower down would not remedy the evil, as the floods come down very rapidly, and the relief is required near Burdwan. The present channels would require to be considerably widened to carry off the surplus water, and we should require besides a new channel about half a mile wide in addition to the Kana and Banka. The land alone for this new channel would cost about 23 lakhs of Rupees, and the embankments on the three channels would cost about 10 lakhs more, making 33 lakhs, and this does not include the land required for the embankments on the Kana and Banka, nor the compensation for the houses on the bank; the latter would form a very heavy item, on the Kana especially. When the channels were opened out they would in all probability silt up in the same way as the Damoodah has done, and the embankments would have to be continually raised and strengthened: this scheme, too, would be entirely unremunerative, as the people whose country would be protected already pay Government for such protection, or at any rate for the maintenance of embankments to ensure such protection, and of course could not be further taxed on this account.

As the Government of India, when reviewing the Reservoir Project, ruled in the 5th paragraph of their No. 182 of 31st July 1868 that no expenditure would be sanctioned for which a good prospect of really tangible income was not clearly made out, and that the outlay of the State should be covered by corresponding income, it is clear that the only project by which the country on the right bank can be saved from periodical inundation is by Reservoirs, and I will now endeavour to show how far this scheme comes up to those conditions.

Estimates have been prepared for three Reservoirs (two in detail), from these it has been ascertained that we can store water at the rate of Rupees 150 to Rupees 200 per million cubic feet. To render the country safe we should probably have to store 50,000 millions, the cost of which would be, taking the higher figure, 100 lakhs of Rupees. I reckon that we cannot depend on more than 200 cubic feet in the dry season from the river without storage; we should therefore require, supposing we could utilize the same amount of water by means of the

canal during the rubbee as during the khurreef season, 18,000 millions cubic feet, the cost of which would be 36 lakhs of Rupees. We should be able to irrigate 300,000 acres, which at Rupees 3 per acre would give a return of Rupees 9,00,000. Supposing the net profits to be 6 lakhs, this would give an income of 16 per cent on the amount utilized and 6 per cent on the whole outlay. It is true that, according to the Raneegunge gauge readings for the last nine years, *viz.*, 1860-61 to the present time, in five years out of the nine the necessity for the Reservoirs would hardly have been required; but as at the time that the rubbee crop is sown it is impossible to tell whether the natural supply of the river will be a minimum or a maximum, we could only arrange with the cultivators for irrigation of the area according to the minimum supply, which, as I have before stated, cannot be safely reckoned at more than 200 cubic feet per second. There is another point in favor of the Reservoirs, *viz.*, that we should, I have no doubt, be able to sell the water at the site at probably nearly as advantageous terms as in the districts through which the canal runs.

If the sale of 30,000 millions was effected at the sites of the Reservoirs, we could always afford to keep the 20,000 millions required for the canal, whether it was eventually wanted or not.

SECTION III.—*Alignment of Canal.*

The alignment of canal remains unaltered up to the 71st mile; it then runs nearly due east, instead of to the south-east as the original line did. At 77 $\frac{3}{4}$ and 83 $\frac{1}{2}$ the canal crosses two Railway Feeder Roads: these will be carried over the canal by bridges, as shewn in plans Nos. 30 and 32. At 82 miles the canal passes through some very low marshy ground; here I propose to place a large syphon culvert as per plan No. 31; from the 85th mile to the Koontee Nuddee there will be no extraordinary works required: I propose dropping the canal into the Koontee Nuddee by a double flight Lock of 8 feet lift each at a point one-fifth of a mile south of the Railway Bridge: the Koontee Nuddee is tidal, and there is at all times of the tide sufficient water. From the Lock to the entrance to the Hooghly the distance by the Koontee is 6 miles: this distance might be reduced by making a cut along the line *a b* dotted red in sheet No. 15: the Railway Bridge over the Koontee has three

water spans of 80 feet each, and there is 12 feet of headway at full tide : the canal along present line is $91\frac{1}{4}$ miles long and 6 more along the Koontee to the Hooghly, making $97\frac{1}{4}$ in all ; but by making the cut suggested to Trebenee Ghaut the distance would be reduced to $92\frac{1}{4}$: the cost of this cut would probably add Rupees 25,000 to the revised earth-work estimate, and a further sum of Rupees 15,000 for a bridge over the Grand Trunk Road.

SECTION IV.—*Haulage on Canal.*

I have, as accurately as I am able, estimated the probable cost of haulage on the canal according to the following data :—An 800-maund or 30-ton boat requires on the River Damoodah one manjee and eight men. Supposing that the same crew is necessary for the boat on the canal, the cost of the men's wages per mensem will be Rupees 56, *viz.*, Rupees 8 for the manjee and Rupees 6 each for the men ; adding Rupees 4 for rope, &c., Rupees 60 per mensem will about represent the cost of the locomotive power of the boat. I reckon that the boat will be able to make three trips from the collieries to Calcutta per mensem, *viz.*, two days in the canal, four days for loading and unloading, and four days back for the empty boat ; 30 tons of coal therefore will have been conveyed 120 miles for Rupees 20 ; the haulage per ton per mile = 1 06 pies, or a little more than $\frac{1}{2}$ d. per ton per mile ; this is assuming that the boat will return empty, which will rarely, I think, be the case.

I find it very difficult to arrive at the cost of haulage on the East Indian Railway ; but I have, from the abstracts of receipts and expenses from January 1855 to June 1858, the time during which only the section from Calcutta to Rancegunge was open, made a rough estimate from which I make the haulage, then, about 3 to 4 pies per ton per mile : the way I arrived at this was by assuming that the passengers were carried on an average 30 miles, the goods 50, and the minerals, of course, the whole distance, *viz.*, 115 miles. I have been informed at the Railway Office that the cost of haulage roughly is now $2\frac{1}{2}$ annas per vehicle : the vehicles as a rule carry 7 tons ; the cost per ton per mile is according to this estimate $4\frac{2}{7}$ pies, or $\frac{1}{2}$ d. per ton per mile.

It has been stated in the 10th paragraph of the Government of India's No. 2341. dated 29th July 1869 that the facilities for sending

coal by the Damoodah to the Hooghly appear to have been somewhat under-stated. From information I had received from the Bengal Coal Company I stated in my report that the cost of carrying a ton of coal by river to Moiraka was Rupees 3-8 per ton, not including losses. From the information I have since received from the same Company, I find that the actual cost of conveyance last year to Calcutta by river, including losses, was Rupees 7-8-11 per ton, and that this year it is Rupees 3-14-8 per ton, so that so far from being under-stated the facilities were really over-stated.

The cost of conveyance of a ton of coal by Railway to Biddabatty is Rupees 4-8 per ton : here a trans-shipment is necessary before the coal can be made over to the purchasers. I will now make an estimate of what the probable cost of carriage by the canal would be.

Say the boat is capable of carrying 40 tons, and that the first cost of such a boat is Rupees 4,000, and that 15 per cent of first cost is taken for interest and wear and tear of the boat, the monthly expenses would be as follows :—

	Rs.
Charge of boat... ..	50
Manjees	56
Tolls through canal according to my estimate } (the Government of India suggest half of this) }	120
Sundry expenses 10 per cent of above	25
	<hr/>
Total	251
	<hr/>

or Rupees 251 for 120 tons of coal conveyed. In this case, too, the boat is supposed to return empty ; cost of conveyance to senders of coal, therefore, would be nearly Rupees 2-2 per ton.

We have then the cost of conveyance of a ton of coal to Calcutta by the different routes as follows :—

	Rs.	As.
By Railway to Biddabatty (actual)...	4	8
„ River Damoodah	3	12
„ Canal	2	2

It is true that the coal would have to be conveyed from the pit to the canal, but so in the case of the Railway would it have to be conveyed by boat from Biddabatty or Howrah to the purchasers, or to the Store-yard : then, again, it is very true that the rail can be carried to the pit's mouth, but up to date it has not been done so, except in one instance, in all the pits belonging to the Bengal Coal Company ; and I presume, if this decreased the cost of conveyance to any extent, it would have been done in all cases long ere this ; as it is, the average distance from the pits to the rail is 1 to 2 miles, and the coal has to be conveyed this distance by carts.

In the 12th paragraph of the Government of India's letter, it has been stated that the question as to whether steam power will be used on the canal either for towage or carriage must at present be a matter of surmise : but it appears to me that it is no more a matter of surmise than that the carrying capacity of a double line of rail is unlimited : the latter assertion is of course founded entirely on European experience, and is not the result of anything learnt from the working on Indian Railways, and if we quote the same experience with regard to canals, we shall find that in almost every instance steam power has been used in England, and with invariable success ; to bear out my statement, I will give examples from a paper and discussion that took place at the institution of Civil Engineers in London in November 1866.

On the Gloucester and Berkley Canal steam tugs were placed upon the canal to do the work formerly done by horses ; the cost of towing by this method for five years was $\frac{1}{13}$ th of a penny per ton per mile, being a saving of not far short of $\frac{2}{3}$ ds of cost of haulage by horses, and this included interest of cost of tugs, repairs, and renewals : for six months ending September 1865, in consequence of a larger and more regular trade, the cost of haulage did not exceed $\frac{1}{13}$ th of a penny per ton per mile. The employment of steam power on this canal has been found in every way advantageous ; economy of work, increased speed, and the silt, which was before deposited on the banks whence it could not be easily removed, has, by the increased speed, been entirely removed from the slopes to the bottom, whence it can be readily taken out by the dredger.

On the Grand Canal in Ireland on a long level of the canal ($25\frac{1}{2}$ miles) towing steamers have been introduced, which can haul three

laden boats, each carrying 40 tons, at the rate of $2\frac{1}{2}$ miles an hour: on this portion of the canal, since steam power has been introduced, horses have been withdrawn altogether.

On the Forth and Clyde and Monkland Canals the use of steam power has proved so successful that the number of steamers on them has increased from 1 in 1856 to 70 in 1866, and it has been found that the cost of haulage by steam is $6\frac{1}{4}d.$ to $7\frac{1}{2}d.$ per mile for 30 to 60 tons, while cost of haulage by horses is about $9\frac{1}{2}d.$ per mile. I may add that the Forth and Clyde Canal between the Frith of Forth and Frith of Clyde is 35 miles in length, and in that distance has 40 Locks, with a rise of about 8 feet each and at distances apart of from 50 yards to 17 miles. The Monkland Canal, 12 miles in length, has 10 Locks, 8 of which are double, each having a lift of 12 feet. Four tugs placed on the Regent's Canal in September 1866 gave the cost of haulage for three weeks $\frac{1}{16}d.$ per ton per mile, and on this canal it has been found that where steamers were regularly used it became a very economical mode of conveying vessels in the canal.

Steamers have also been used with great success on the Ashby-de-la-zouche Canal for carrying coal; the speed varying from $1\frac{1}{4}$ to 5 miles an hour. On the Grand Junction Canal the cost of haulage by Engine-boat *Dart*, 70 feet in length, 7 feet beam, and drawing 4 feet when loaded, was $\cdot 184$ of a penny per ton per mile, or $\frac{1}{2}d.$ per ton per mile.

On the Aire and Calder Navigation steam power had been employed since 1836, confined to the main line between Leeds, Wakefield, and Goole, a distance of 36 miles. Between Leeds and Goole there were 10 Locks having a total fall of 66 feet, and between Wakefield and Goole 7 Locks, with a total fall of about 50 feet. Improved means of steam haulage had been introduced in 1853, which had been continued and extended to the present time. The average cost of haulage by steam tugs carrying cargo for the past seven years had been $\cdot 085$, or $\frac{1}{16}d.$ per ton per mile, at an average speed of $4\cdot 5$ miles per hour, and at this speed the canal banks had sustained no injury. The cost of haulage by tugs solely employed for towing at a speed of 3 miles per hour was $\frac{1}{16}d.$ per ton per mile against stream and $\frac{1}{12}d.$ per ton per mile down-stream.

It appears, then, from the above examples that steam power has been used successfully on almost all the canals of Great Britain, and it must be remembered at the same time that none of the canals had been designed in the first instance for steam traffic; they are nearly all small in section, and cost of working therefore is greater than it would be if there was a greater disproportion between the sectional area of the vessel and canal.

In Holland and Sweden also, where the subject of steam traffic on canals has been much studied, it has been found that steam power will always pay on canals; such being the case, I think there is no doubt that steam power will be used on the Damoodah Canal, provided the section of the canal will admit of it: the number of Locks is nothing compared to the number on many of the canals in England on which steam power has quite superseded the use of horses. Supposing, therefore, that steam power is used on the canal, the cost of haulage will be probably much less than my estimate, *viz.*, $\frac{1}{8}d.$ per ton per mile: on the Railway the cost of haulage is probably not less than 2 to 3 pies, or $\frac{1}{4}d.$ to $\frac{3}{8}d.$ per ton per mile: it is true that I have not taken into account the greater speed at which goods would be conveyed by the Railway, but this is a matter of no importance to minerals: regularity of transmission can be considered as certain by the canal as by the Railway, probably more so, as it is supposed that the reason which led to the offer by a private Company to construct the canal was principally to obviate the difficulties experienced by the Coal Companies in sending their coal by the East Indian Railway. There is another point which renders the comparison of cost of haulage between the Damoodah Canal and East Indian Railway more favorable than such comparisons generally between canals and Railways constructed between two places, *viz.*, that there is hardly any difference in the distance; if anything, the canal is the shorter, whereas as a rule in England a Railway is generally much shorter than a canal between same termini.

SECTION V.—*Cost of Works.*

The estimate for earth-work shows a reduction on the original estimate of $4\frac{1}{2}$ lakhs of Rupees: this reduction is owing to a shortening of the canal by 9 miles, by which over one lakh of Rupees is saved, and

Earth-work.

also by the very considerable reduction made in the cross section of the whole line from the 28th mile to the end: in the last portion the cross section of the channel is only three-fifths of the channel as originally designed.

I have entered such drainage cuts as I consider may be necessary, and I have also entered the cost of cutting the channel from the Koon-tee to Trebenee Ghaut: this will shorten the distance into the Hooghly by nearly 5 miles, and will cost about half a lakh, *viz.*, 25,000 for earth-work entered in estimate and the similar amount for a bridge to carry over the Grand Trunk Road. I have also entered Rupees 36,000 for a temporary road along the whole line of canal which it will be very desirable to make in the first instance.

The designs for the head works remain as they were originally, slight alterations having been made in the entrance Lock and head sluices, according to Colonel Anderson's remarks.

Head Works.

Locks and Falls.—The locks have been kept the same size as originally designed, and this is ample for such steamers as have been used on the Severn, and which, I think, would answer particularly well on the Damoodah Canal: the steamers are 70 feet long, 12 feet beam, and $3\frac{1}{2}$ draught of water, fitted with a pair of small direct acting engines, working direct upon a pair of twin-screws 2'-6" in diameter: such a vessel is capable of carrying 40 tons of cargo, and of tugging two or three canal boats with 30 tons in each.

Should the traffic increase to such an extent as to demand more lockage room, it seems desirable to construct duplicate Locks. I have, however, estimated for a Lock of the size proposed by Colonel Anderson of 10 feet lift, and find that the cost is Rupees 9,000 more than for a Lock of same lift of the size estimated for; if, therefore, it is decided that the Locks shall be made of the size proposed by Colonel Anderson, the cost of all the Locks will be about 2 lakhs of Rupees more than the present estimate, which has been of course increased by the additional thickness to the walls and other alterations recommended. I have designed the Locks so that they can be raised 3 feet at any time, when

the extra supply is carried by the canal: the gates and quoins I have estimated to make the full height at once.

The length of the falls I have arranged for the 1,500 cubic feet supply, diminishing the length in proportion as the water is abstracted: by a no great additional length it would be possible to pass the double supply, but the velocity would be much greater and the wear and tear considerable; it seems preferable therefore to make duplicate falls when the extra supply is required than to give the additional length now. The body and wing-walls have been designed so that the additional 3 feet in height can be given at any time.

The designs for the aqueducts are according to the alterations alluded to in the estimates for the original designs; they also have been designed to carry the extra 1,500 cubic feet.

Aqueducts.

I have arranged for two escapes, one at the 12th mile and the other at 49½ mile; the former is capable, with 1½ feet of water going over, to discharge 1,000 cubic feet per second, and is supposed to meet the contingencies of one of the gates in the head sluices giving way; the other is at the Banka, and is capable of discharging 400 or 500 cubic feet per second, with a foot in depth going over. These two escapes will, I think, be ample: they are both very conveniently situated, as the water can be discharged into the Tumlah and Banka Rivers. The 66th mile, the point suggested for an escape by Colonel Anderson, is not a convenient point, and is in some respects objectionable; in the first place, the only channel that the water could be easily discharged in would be the Damoodah itself, and water would have to be passed through the embankment by sluices, which would be closed when the Damoodah was above a certain height; the escape, therefore, would be no escape probably at the very time it was required. The water might be taken between embankments to the Kana Nuddee, but this would involve an embanked channel of 8 or 9 miles in length and the cutting away of the dams in the Kana itself. I think that the two escapes I have arranged for will be sufficient, more especially as we have by the arrangement of the head works control over all the water that enters the canal except the rainfall.

Escapes.

Where the canal crosses any pukka road I have arranged for bridges over the canal: through Burdwan there will be a bridge at the Lock No. 53 quite wide enough for the traffic at that part, and I have arranged for two

Road Bridges.

other bridges at the 54th and 55th miles; by making a metalled roadway along the north bank of the canal along this distance, *viz.*, from 53rd to 56th mile, and having the roads turned to these bridges they will be ample, I think, for all the traffic.

There is besides a bridge at each Lock: at the other village roads or tracks which are ploughed up during the rains, ferry boats can be supplied when they are required.

These will be given as originally designed at 1 mile 6 furlongs, 3 miles 3 furlongs, and 18 miles 7 furlongs, and there will be one more at

Syphon Culverts.

8½ miles. There will be 22 small syphon culverts in the first 28 miles, according to Drawing No. 5; 3 in the distance from 28 to 33 miles according to Drawing No. 18; 12 in the distance from 33 to 49; and 30 in the distance from 49 miles to end, according to Drawing No. 23: these with the drainage cuts I have provided will, I think, be ample to pass the drainage from one side to the other.

The estimate for the land I have entered as in the original estimate:

Land.

we shall certainly take up less, but I find from what we have already had to pay that my estimate was too low originally.

I propose to build the following Bungalows along the line for the residence of Officers and Subordinates and for the purposes of inspection:—

Accommodation.

1	Bungalow for Executive Engineer	at Rughoonath Chuck...	Permanent.
1	ditto „ ditto	at 83rd mile	... ditto.
1	ditto „ Assistant Engineer	at Rughoonath Chuck...	ditto.
1	ditto „ ditto	at Singarun	... Temporary.
1	ditto „ ditto	at Tumlah	... ditto.
1	ditto „ ditto	at 52nd mile	... Permanent.
1	ditto „ Sub-Engineer	at Rughoonath Chuck...	ditto.
1	ditto „ Quarryman	at Mungulpore	... Temporary.

1	two-roomed	Inspection Bungalow	at Tumlah	...	Permanent.
1	ditto	ditto	at 24½ mile	...	ditto.
1	ditto	ditto	at 35th „	...	ditto.
1	ditto	ditto	at 45th „	...	ditto.
1	ditto	ditto	at 55th „	...	ditto.
1	ditto	ditto	at 65th „	...	ditto.
1	ditto	ditto	at 75th „	...	ditto.
1	ditto	ditto	at 85th „	...	ditto.
1	ditto	ditto	at 91st „	...	ditto.

9

Drawing No. 36 shews design for the Executive Engineer's bungalows; Drawing No. 35 for the two-roomed bungalows.

Of these the bungalow for Quarryman at Munglepore has already been completed at a cost of Rupees 1,500, and the bungalow for Executive Engineer at Rughoonath Chuck and for Assistant Engineer and Sub-Engineer at that locality have been sanctioned and are in progress

The bungalows according to Drawings Nos. 34 and 36 will be for residences, and the inmates will pay rent at the rate of 7½ per cent on the cost.

The bungalows according to Drawing No. 35 will be occupied by Overseers free of cost, leaving one room and a bath-room for the Inspecting Officer.

Colonel Anderson in paragraph 29 of his Note says that on a navigable canal, where the Officers and Subordinates will have facilities for moving about by water, and may live *pro tem* in boats, the provision of chowkies is not required to the same extent as on some of the canals in the north of India. I dissent entirely from this idea; the canal will not be navigable certainly for four years, and during that time the greatest inspection will be required, and it is vain to expect that such supervision will be effectual during the months from April to November if the accommodation afforded to Inspecting Officers is only that supplied by a tent or mere temporary shed; and the suggestion regarding the Inspection Bungalows in connection with the Damoodah embankments being available for the canal would apply with about the same force to the hotels in Burdwan and Calcutta.

There are only four Embankment Bungalows parallel to the line; two of these are about 4 miles from the canal, and one of the remaining two is near Burdwan, where it would hardly be required: any one stopping near there would probably go in to Burdwan; the remaining one might be made available if a road about half mile long was made, which would be passable during the rainy season.

I have no hesitation in saying that it is true economy to provide efficient shelter. There are few men who care to stay in a tent or a temporary shed during the hot and rainy months of the year, and of the few that are indifferent to the inconveniences of heat and wet there is but a very small proportion blessed with constitutions that can stand it. With good shelter, such as the bungalows estimated for afford, the Officer or Subordinate can be as comfortable as in his own dwelling, and he is not driven to scamp the work for which the visit is made, and which may require his presence in the locality for some days.

I have seen most of the Inspection Bungalows in Lower Bengal, which are of all descriptions, and I have no hesitation in saying that those embankments and roads are in the best order which have in connection with them Inspection Bungalows that are comfortable and afford really good shelter against heat and moisture, and I do not think the Government have cause to regret the expenditure of a single penny that they have incurred throughout Bengal for these Inspection Bungalows. The amount now estimated for is, I consider, the very least that can be allowed, and is in no way in excess of reasonable wants.

The whole expenditure will be as follows :—

1	Executive Engineer's Bungalow and Office at Rughoonath Chuck	...	...	...	...	Rs.
		...	...	...	...	12,300
1	ditto ditto ditto at 83rd mile...					14,806
2	Assistant Engineer's Bungalows at Rughoonath Chuck and Tumlah	...	...	...	...	13,440
2	ditto ditto at Singarun and 52nd mile	...				13,440
1	Bungalow for Sub-Engineer at Rughoonath Chuck	...				4,061
1	ditto for Supervisor at Munglepore	...				1,694
1	two-roomed ditto at Tumlah	...				4,770
8	ditto ditto along line	...				40,520
	Total	...				<u>1,05,031</u>

I have entered the cost of distributaries as in the original estimate, as until they are surveyed and levelled, it will be impossible to obtain their cost accurately : their alignment has been determined from the cross sections of the country, which were taken to determine the main line of canal.

I have allowed Rupees 2,00,000 for baling water and 2 lakhs for making temporary dams.

Baling, making, and cutting Dams.
Tools and Plant.

The cost of Tools and Plant I have entered at Rupees 2,00,000.

The cost of the whole Project is Rupees 51,36,898 or 51½ lakhs of Rupees.

In the 14th paragraph of Government of India's letter No. 234Z. of 29th July 1869, it has been ruled that the questions which have been raised in the Officiating Inspector-General's Note will have to be carefully considered and replied to before His Excellency in Council can feel satisfied that the calculated returns from irrigation rest on a firm basis. Colonel Anderson has misunderstood the description given in my report, and has described a system of husbandry which applies in no way to the Burdwan district, nor in fact to any of the country that I am acquainted with commanded by the canal; in the first place, Colonel Anderson states "that the rice crop must already be raised by irrigation:" this is not the case; for, out of the 600,000 acres of *amun* rice cultivation in the Burdwan district, nine-tenths of it probably are dependent entirely on the rainfall: it is quite true that every natural means of irrigating is taken advantage of; many of the tanks and any cuttings either for roads or railways which are conveniently situated are utilized, and the water lifted from them on to the fields; but the quantity of water so available is exceedingly limited: we have had ample proof this year of how thoroughly the rice crop of the Burdwan district is dependent on the rainfall: in August only 6 inches fell against 12 inches, the mean for the last 10 years, and the rice crop has consequently suffered so much in many parts of the district that it is supposed that it will not yield more than half an average crop: rain fortunately fell towards the end of August, otherwise there would probably have occurred such

Returns from Irrigation.

distress as would have proved, without further discussion, the utility, I might almost say the necessity, of a canal; as it is, even the half crop is not yet assured, as the season holds out every appearance of being a peculiarly dry one.

The cultivators apparently do not see the anticipated difficulty in practice of distributing water to the rice-fields. I have spoken to many since my original estimates were submitted, and they have all appeared delighted at the idea of a canal which would save them from their present necessity of depending on the rainfall for their cultivation. I expressed a doubt in my original report as to whether the ryots would take water for the rice crop; but, as far as the Burdwan district is concerned, I have no doubt whatever on the subject now, and I feel quite confident in my own mind that the ryots would pay for water for the rice crop willingly.

In the 38th paragraph of his report Colonel Anderson has gathered from my remarks something quite different from what I intended to convey: the dams made in the water-courses in the Hooghly District are more for the purposes of drinking, washing, and stocking fish than for irrigation; in fact, for the latter purpose, there is not sufficient water (the dams being made at about $\frac{1}{4}$ to $\frac{1}{2}$ a mile apart), and the banks are so high that it would hardly pay to lift the water. I only mentioned the necessity of cutting the dams to drain the channel, as I considered, and still consider, that the use of the filthy water of these stagnant pools, together with the defective drainage caused by the dams, has more to do with the so-called Hooghly epidemic than any other cause. In the Burdwan district the country has a fall of nearly 4 feet per mile; drainage therefore is easy enough and by the natural drainage channels that now exist. With regard to the Hooghly district, the surplus from the artificially irrigated fields would certainly gravitate to the lowest lands; but these lands are already swamped to such an extent during the rains that no cultivation is possible till the cold weather; they would not suffer more than they do now in the absence of artificial irrigation, but these swamps could all be easily drained so as to ensure their being cultivated in the rains; and if a scheme of drainage was carried out in conjunction with the irrigation scheme, there would be no difficulties such as are anticipated, for the owners of the swamps would be able to raise a rice

crop during the rains, a great consideration with the Bengallee cultivator, and whatever water did come to his fields would be drained, if necessary, by the drains cut in connection with the drainage scheme.

It is impossible to tell what the returns from irrigation will be ; but, judging from the statement of zemindars and cultivators and from the partial drought that has taken place in two consecutive years, at the time when the crop requires water, and the necessity consequently for irrigation for the security of the rice crop, and from the willingness of the Bengallee cultivator to adopt any measure that will improve his land, provided that the cost of such improvement is within his means, I think we may safely reckon on being able to dispose of all the water the canal can distribute at rates probably much higher on an average than have been estimated : this, together with the certain large profits from navigation, is quite sufficient to recommend the construction of the canal to private enterprise ; while for the Government there is the additional great inducement of the assurance that the canal will be the means of insuring the safety of the greater portion of the staple crop of two of the most populous and most fertile districts in India, a crop, too, which suffers now to some slight extent every year, and which has suffered this year very considerably, from drought.

From Commissioner of Burdwan; to the Government of Bengal,—(3rd January 1870.)

I have the honor to acknowledge the receipt of your No. 17907. of 2nd September ; and, in reply, to submit, for the information of the Lieutenant-Governor, the reports, in original, as noted in the margin, with their enclosures, from the Collectors of Burdwan and Hooghly. If the reports are printed, I beg to be favored with copies of them.

No. 370 dated 13th December.
 „ 566 „ 26th „

2. It will be seen from the replies of the Collectors that it is their opinion that very great benefits may be confidently anticipated from the irrigable properties of the projected Damoodah Canal. This opinion appears to be supported by all the zemindars and ryots who have been consulted by those Officers.

3. With regard to the extent to which Irrigation is already practised in Hooghly and Burdwan, the evidence seems to me to shew ~~that there is~~ *no such thing as irrigation in its scientific and systematic sense.* To lead a little water from an isolated tank to an adjacent field is no more to be called irrigation than if that term were applied to an English gardener watering his vegetables from a water-engine. The only thing approaching to a system of irrigation is to be found in the erection of a few barriers or temporary annicuts across the beds of a few rivers (such as the Darkissor and Selye in Hooghly, or the streams mentioned in paragraph 20 of the Burdwan Collector's letter) to pen up the water in the cold weather, so as to lead it to a few of the neighbouring fields. But the area thus affected is very small; and little, if any, of it will come within the range of the projected canal. If, however, this is to be called irrigation, the term may also be used to include the effect of the ordinary rains of heaven, which provide the water on which the growth of ⁹⁹⁹_{1,000}ths of the ordinary crops is dependent, and this really seems to be the interpretation which must be attached to paragraph 41 of Colonel Anderson's Note of 31st May 1869.

4. Therefore, in reply to the remark of the Government of India quoted in the 4th paragraph of your letter, I should say that there is no present defective system of irrigation which the people are to be induced to give up. The defect with which it is necessary to deal is rather to be found in the irregular distribution of the annual rainfall noticed in the 2nd paragraph of your letter, a defect which it is the express object of the canal to remedy. As Mr. Adley remarks in his Drainage Report—"In all countries the provisions of nature in this respect are irregular and inadequate, and require to be supplemented by artificial aids."

5. It is the rainfall, early or late, scanty or copious, which alone will affect the demand for irrigation water, if the cultivators are left to themselves from year to year to take water. If all the irrigable land within reach of the canal and its disbristribaries is made liable by law to a certain rate for the use of the water, the cultivators will gladly avail themselves of the certainty thus given them, and the only dispute will be between them and the land-owners for their share in the profit as is sagaciously pointed out by Baboo Joykissen Mookerjee.

6. It is, of course, a very interesting question to consider if the canal, combined with a system of drainage, can be made to remedy the alleged unhealthiness of certain parts of the district. But it seems hardly fair to demand of the supporters of the canal that they are to undertake a sanitary system also. The canal with its distributaries, as at present projected, will be a slight scratch across a tract of country which has not been specially unhealthy. If a scratch is made on a man's leg, it is not expected to cure an organic disease in his chest. I fail to see how the canal is to be made responsible for the removal of existent stagnant pools, except in an infinitesimal proportion, nor does there seem any sufficient reason to apprehend that there will be any such escape of surplus water from the canal into the irrigable lands as to interfere with, or increase the difficulty of, the general drainage of the country.

7. With reference to the 7th paragraph of your letter, it may be safely affirmed that the only recognized proprietary rights as to water-supply are those arising from the formation of a few barriers or temporary anicuts across the bed of the rivers noticed above in paragraph 3 of this letter. But these barriers are always so slightly made that they are carried away by the first flood as soon as the rains begin. The Collectors of Burdwan and Hooghly both remark that the Civil Courts have recognized the right of the land-owners to erect such barriers, and they propose legislative interference with these rights. I think that it should first be carefully ascertained if the projected canal will really interfere with any of those few rivers in which such barriers are constructed. It is surely not desirable to raise an alarm about difficulties which will not be met within the execution of this particular project.

8. In the 38th paragraph of Colonel Anderson's Note it is stated, on the authority of Captain Garnault, that it is a common practice to throw bunds across the water-courses, and he attributes the unhealthiness of the districts around Calcutta to this cause. But these bunds are of an entirely different character from those to which reference is made in my last paragraph, and are chiefly to be found in the beds of the Saraswuttee and other old channels of rivers which have now silted up. The cultivators have taken possession of the beds of these rivers permanently, and I need only refer to Mr. Adley's report for a full description of them and of the bad effects produced by them.

9. After a careful perusal of Mr. Adley's report on the drainage of the Hooghly, I think it most undesirable that the question of the canal should be entangled with the question of drainage and sanitary improvements. The canal will stand or fall by its own merits. Its construction will confer a very great benefit on a portion of two of the richest, and hitherto most neglected, districts of Bengal, and it will certainly be a profitable investment of money, provided that the works are well and skilfully executed. The separate question of the drainage will also, I trust, soon meet with due consideration in connection with Mr. Adley's reports, but there is no sufficient reason to permit it to impede the progress of the canal.

10. I have had a careful search made in regard to the cases decided by the High Court regarding the use of the water and the rights appertaining to it. There do not seem to be any cases of much importance laying down any very authoritative doctrines on the subject; but, as the legal books of reference in my Office are not complete or numerous, it may be advisable to consult the Legal Remembrancer on this part of the subject if it is deemed necessary.

From the Collector of Hooghly, to the Commissioner of the Burdwan Division,—(13th December 1869.)

I have the honor to acknowledge the receipt of your letter No. 77. of the 30th November drawing my attention to the orders of Government forwarded with your letter of the 2nd September, calling for a report on the anticipated beneficial effects of the canal from the Damoodah to the Hooghly.

2. These instructions reached this Office some weeks before I rejoined this appointment. My predecessor, I find, called for the opinions of various zemindars in the district on the subject, but all the replies not having been received, my attention was not, I regret to say, directed to the fact of such a report having been called for until I received your reminder under acknowledgment.

3. From the correspondence I perceive that the Collector of Hooghly has, on a previous occasion, reported on the same subject, but this again was during my absence on leave, so that it thus unfortunately happens that

this is the first time that the matter has come before me; and I hope that this circumstance may be taken as some excuse for any shortcomings in the present report. Your letter now calls urgently for a reply; and I therefore think it better to state such facts as are within my knowledge, or that I have been able to collect from somewhat hasty inquiries rather than delay this report any further.

4. In answer to Mr. Taylor's letters, the zemindars have generally sent in replies favorable to the proposed scheme; none of these contain any matter worthy of notice, except the letter of Baboo Joykissen Mookerjee, which I enclose.

5. That gentleman, as usual, discourses fully and intelligently the questions addressed to him; and, as regards the probable demand for water for irrigating purposes, I think no better evidence could be had than that of this large landed proprietor, who states that he has re-dug and excavated no less than 50 tanks within his estates, and that, although he asks no rent for the use of the water, he still finds that the outlay he has incurred is remunerative simply from the higher rents which he is able to ask for lands where the means of irrigation are thus provided.

6. Another gentleman, Baboo Obhoy Churn Nundy, gives it as his opinion that the people will "gladly make use of the water, provided they can get it at a trifling cost;" at present, he says, "the supply of water cost them nothing but the labour."

7. The latter remark touches upon a subject of no little difficulty, *viz.*, the mode of distributing the water. For this no doubt the experience of Orissa and the North-West Provinces will afford the best guide; but I would observe that at present it is not clearly understood whether when it is proposed to charge a certain rate per beegah for water, it is intended that this is the cost of water actually supplied to each ryot on his land by contrivances for which he will not have to bear any portion of the cost, or only that he may take the water at the rate mentioned from the distributaries or other Reservoirs conveying it to his land as best he can.

8. I need hardly point out how much the success of the whole scheme at starting depends on the ryot being able to secure at once a direct pecuniary advantage by the new mode of irrigation.

9. I will now proceed to notice more particularly the points to which attention is drawn by Colonel Rundall's letter No. 1790/I. of 2nd September last.

10. In paragraph 2 it is said that the Lieutenant-Governor desires to have a further report with reference to the question whether irrigation is now practised in this district, and to what extent.

11. To make my reply to this question clear, I think it will be as well that I should state briefly what are the various kinds of land in this district which require irrigation, and also those in which irrigation is not practised. I do not find that this has ever yet been clearly explained in the published correspondence, though, probably, it is well known to the Engineers who have made the preliminary enquiries on the subject of the canal.

12. In the greater portion of the Hooghly district, and in all that portion which the proposed canal will traverse, lands are divided into two principal classes. In the first division are classed the "sona danga" or high lands. In the second are the "sallee" or low lands.

13. The "sona danga" lands are of several descriptions, the rent varying from Rupees 6 to 3 (I speak now of this one part of the district only) according to the quality of the land.

14. The "sallee" lands are similarly sub-divided into several classes according to the quality, the rent varying from Rupees 5 per beegah to Rupees 2.

15. The "sallee" lands, I perhaps need hardly explain, are so called from the fact that one crop only in the year can be grown on them. This is almost invariably the rice crop known as the "amun" or "hoymontie" crop, which is gathered in the months of December and January.

16. These rice lands are under ordinary circumstances never irrigated, except for a few days in the month of October or beginning of November after the rains have ceased. On some lands of this description the water lies all the year round; on others the water remains from June to October. There would be no demand, therefore, under present circumstances, for artificial irrigation for these lands, except at the season of the year I have mentioned, unless there should be a total or partial failure of the ordinary rains. In that case a plentiful supply of water at a critical time might, no doubt, save the whole crop from destruction.

17. It may, therefore, be safely said that there can be no certainty of any steady demand for water for the irrigation of this class of lands at any period of the year, though at any moment such a supply might be invaluable.

18. As to the specific areas of each of the description of lands which I have mentioned, or the proportion which the high lands bear to the low lands in extent, it is impossible to make any approximate calculation.

19. In the large village of Boinchee, near which the canal will enter the Hooghly district, out of 2,000 beegahs, 300 beegahs are "danga" or high lands, but the extent of each description of land must vary in each part of the district according to the character of the country, and it cannot be said that the same proportion between the areas of the two classes of land will be found elsewhere.

20. In the answer from this Office quoted by Captain Garnault, I see it stated that the ordinary weight of paddy produced from one acre of land is 15 or 18 maunds. This, I think, is probably a clerical error, and that it was intended to give the weight per *beegah*, as this would be a proper estimate. As to any difference in weight between rice crops artificially irrigated and those not so reared, no opinion can be offered, as no rice crop is systematically reared by artificial irrigation, but the aous crop of paddy gathered in August is less in weight than the winter crop in the proportion of 12 maunds per beegah to 18 maunds.

21. The average profit per beegah of sallee land which a ryot may expect to derive in this part of the district under favorable circumstances from a winter rice crop after payment of rent and all costs of cultivation would be from Rupees 8 to 7.

22. The account would probably stand thus—

<i>Debit.</i>	Rs.	<i>Credit.</i>	Rs.
Cost of cultivation ...	3	By sale of paddy ...	16
Rent ...	5	Ditto straw ...	4
Cost of reaping and storing, &c.	3		—
	—		
Total ...	11	Total ...	20
Balance net profit per beegah ...	9		—

23. Whether it would be possible to introduce an improved system of agriculture on lands of this class is a question on which I hardly feel competent to offer an opinion. It may be, however, observed that at present a superfluity, and not a want of water, is the obstacle to growing other and more remunerative crop than rice on these lands.

24. A thorough system of drainage must, therefore, precede any attempt to alter the existing mode of cultivation ; but, supposing this to have been effected, as no difference exists in the soils of the two classes of lands, it is not credible that the ryots could be so blind to their own interests as to neglect the certain means of increasing their profits if placed within their reach.

25. The other class of lands known as “sona danga” lands command, as I have already stated, the highest rents.

26. From these lands in each year an “aous” crop of rice is usually first taken. This is gathered in August, after which potatoes, mustard, kullais of all kinds, such as peas, gram, moogh, mosoor and mashkullai, water-melon, radishes, barley, and vegetables of various kinds are sown.

27. If, however, rice is not grown, and only a single crop is to be raised in the year, then either sugar-cane, cotton, turmeric, flax, jute, begoons, plantains, and in certain favorable spots the mulberry and lime trees are grown. None of these admit of a second crop, except jute.

28. The “aous” crop of rice is seldom artificially irrigated, but in the month of June, should the first down-pour of rain be late, or the supply insufficient, irrigation is resorted to.

29. For almost all the other crops mentioned, artificial irrigation is indispensable, the quantity of water required varying according to the nature of the crop grown, sugar-cane requiring most care and irrigation during the whole time the crop is on the ground, while the various kinds of kullais require less than any other ; jute alone is seldom irrigated at all.

30. The crops thus raised on these lands I should class in the following order as regards value and the profits to be made out of them.

These being calculated after payment of rent and costs of cultivation of all kinds :—

1st,—Sugar-cane per beegah, Rupees 40 to Rupees 30, requiring irrigation throughout the year.

2nd,—Begoons, plantains, Rupees 25 to Rupees 10 per beegah, requiring constant irrigation.

3rd,—An aous crop of rice, with a second crop of potatoes, per beegah, Rupees 25 to Rupees 12. The rice requires little irrigation. The potatoes are planted in October, and must be constantly irrigated for the following three months :—

4th,—A crop of rice, with a second crop of mustard, per beegah, Rupees 15 to Rupees 10. The mustard requires but little irrigation.

5th,—An aous crop of rice, with a second crop of kullai of any kind, per beegah, Rupees 8 to Rupees 6. The kullais require still less irrigation.

6th,—Jute per beegah, Rupees 8 to Rupees 7. This requires very little irrigation.

31. Independently of these there are garden lands, of which the value of the produce depends on the species of fruit grown, and the age of the trees. “Pân” is also cultivated in some parts of the district and requires a plentiful supply of water. The profits are very large, but certain peculiarities of soil are necessary, and confine its cultivation to a few favored spots.

32. I omit any estimate of profits from a cotton crop, as the cotton grown in this district seldom finds its way into the market, and is chiefly reserved by the cultivators for domestic use.

Perhaps Rupees 10, or Rupees 12 per beegah may be considered a fair estimate of the value of a cotton crop.

33. Water is never paid for. The cost of irrigation as practised in this district is simply the cost of the labour required for raising the water and conveying it to the ryot's land.

34. The expense, therefore, necessarily varies according to the distance the land happens to be from the Reservoirs from which it has to be taken, whether that be a tank or a khall, and the amount of irrigation required for each particular crop.

35. No one average, therefore, can be stated of the cost of irrigation per beegah. Perhaps it may be roughly calculated that the cost of irrigation for a beegah of sugar-cane during the year will amount to Rupees 4; while for a crop of potatoes, under ordinary circumstances, Rupees 2 or Rupees $2\frac{1}{2}$ might cover the cost.

36. From the above it will be perceived that the most remunerative crops are undoubtedly those which require constant irrigation, and consequently the kullais, and similar crops, are only grown when the supply of water is scanty.

37. The facts and figures are, I fear, somewhat meagre; but such as they are, I believe that they can be depended on as accurate, and they are sufficient to shew the immediate and certain advantage which must accrue from any system by which an abundant supply of water can be procured at a cheap rate.

38. The rate mentioned by Captain Garnault, Rupees 3 per beegah, is certainly not too high; but it would be a mistake to make any increase in the charge on account of a second crop on the same land, since the most profitable crops are often those which admit of no second crop.

39. As regards the probability of the ryots taking advantage of the improved means of irrigation placed within their reach, I am of opinion that for the better class of lands on which sugar-cane, pân, potatoes, kullais and vegetables, and similar crops are grown, the use of water for irrigation is only limited by the supply.

40. Ordinarily the water is not conveyed for more than four or five hundred yards from the tank or khall.

Baboo Joykissen Mookerjee states that "the custom in regard to the use of the water is controlled by prescription, and that the privileged ryots will on no account allow others to take the water, and that disputes, affrays and bloodshed take place when a stranger attempts to encroach on their rights."

41. I have myself often noticed how small comparatively is the irrigated area on the side of a tank or khall, and what Baboo Joykissen states is no doubt the cause of this.

The jealousy, too, with which the privileged ryots guard their rights even in years when water is plentiful, arises from the fear that what is permitted in a year of plenty may be claimed the next year as a right, when the supply of water is scanty.

42. From all such facts it is clear that, provided the rate charged for water does not exceed the present cost of labor in raising it, the demand for water for irrigation will only be limited by the area of the lands in each village which are suitable for irrigation. The rate suggested by Captain Garnault, and even a higher rate, will, in my opinion, ensure such a demand, if it is intended that the water shall be supplied to each ryot on his land at this rate.

43. In regard to the low lands on which throughout the district the amun rice crop is now raised, there will be no demand for water for irrigation, except in exceptional years, when the ordinary rain-supply fails; but should an improved system of drainage enable other crops to be raised on these lands, there can be no doubt of an equally certain demand for water for irrigation for these lands.

44. With reference to paragraph 7 of Colonel Rundall's letter, I beg to state that, beyond the prescriptive rights of the ryots to take water from certain tanks and khalls, the only rights in regard to irrigation which I know of are those claimed by various zemindars to erect dams across the running streams of the district in order to keep back a supply of water, during the dry season, for the purpose of irrigation.

45. The bad effects which have arisen to the whole district from this practice have frequently been represented.

The numerous embankments raised have no doubt interfered with the drainage of the whole of this part of the country. These evils are noticed by Captain Garnault, and again by Colonel Strachey in the 17th and 19th paragraphs of his letter of the 29th July, and I need not more particularly refer to them.

46. I would only observe that the right to these dams, on proof of the practice having continued uninterruptedly for a period of 12 years, has been affirmed by the Courts.

The Magistrate is, therefore, unable to interfere without running the risk of a suit for damages against himself personally, which the proprietors of this part of the country are only too ready to bring.

47. I think that the interference of the legislature is urgently called for to enable the executive authorities to remove these dams or embankments, when, by the evidence of competent Engineers, it is established that such obstructions are interfering with the natural drainage of the country.

48. From the indifference which has been displayed in regard to such matters hitherto, I fear that the evil has now attained a magnitude which can only be remedied by such an enactment as I have suggested.

From BABOO JOYKISSEN MOOKERJEE, Zemindar, Otterparah, to the Officiating Magistrate and Collector of Hooghly,—(dated 28th September 1869.)

In reply to your letter No. 406 dated the 20th instant, enclosing copy of a letter from the Joint-Secretary to the Government of Bengal to the Commissioner of Revenue, Burdwan Division, I have the honor to submit the following opinion on the points mooted therein :—

The irregularity in the periodicity and fall of rain in these districts during the last few years was an exception and not the rule. It might be safely asserted that in the Burdwan and Hooghly districts, if not in the whole of Bengal Proper, there is a good fall of rain every five years out of every ten. In such years the projected canal water will be had recourse to only to a partial extent in irrigating such portions of the lands sown with *ous* or *amun* paddy, where the fall of rain is scanty, and also for watering the cotton, sugar-cane and *rubbee* crops. If, however, the present obstructions to free and uninterrupted drainage be removed, and if the ryots find by a few years experience that the fertilizing properties of the Damoodah water yield such a return over and above the average out-turn of previous years, that it more than compensates the expenses incurred on account of it, there will be an eagerness on their

part to avail themselves of the canal water which might satisfy the highest expectations. A few years back one would have been incredulous of the immense sums that are now freely spent by the ryots in the Hooghly and Burdwan districts in purchasing castor cakes for manuring their fields, and I am sure that with regard to the canal water the Bengal peasantry will not be slower than any other class of ignorant men in choosing the standard in a contest of self-interest against antiquity. As to years of drought, it is hardly necessary to say that the canal water will be very largely availed of; and, if the theory that the destruction of the forests and forest-trees is likely to make irregularity and insufficiency of rain an "institution" of the country, unfortunately proves to be true, then the means afforded by the projected Damoodah Canal for an unfailing and constant supply of fertilizing water for the purposes of irrigation will be a real boon to the country.

With regard to the question whether or not the supply of canal water to the ryots will interfere with any of the proprietary rights of the landholders, I beg to observe that in the Hooghly and Burdwan districts the landholders have no sort of engagement with the ryots for the supply of water. Every ryot waters his fields in years of drought the best way he can, generally by drawing water from the nearest tank or khall. The zemindars charge no fee for the water taken from the khalls which run through their estates, nor is there any specific charge for water taken from the tanks. The usual practice is that a certain number of the ryots rent a tank from the zemindar for a certain number of years, during which they divide the fish among themselves and draw water from the tank for irrigating their lands in seasons of scarcity of rain. In some instances, not a few, when the tanks are situated in the open fields the ryots pay no rent at all, and the zemindar's gomastah merely takes the fish. Water from such tanks is allowed to be taken only by those whose predecessors used to take it, and disputes, affrays and bloodshed take place when a stranger attempts to encroach upon their rights. The usage in this particular is entirely controlled by prescription, and the privileged ryots will on no account allow others to take the water. In years of extraordinary droughts however, when water fails in the irrigating tanks, the ryots apply to private individuals who have tanks in the locality, and pay lump sums for purchasing water for their fields. In the Hooghly and Burdwan districts most of these irrigating tanks and *khalls* have more

or less gradually silted up, but in some places the tanks have been re-dug for the purpose of restoring them to their primitive usefulness. I have had about 50 such tanks re-dug and excavated in my estates; and, although I receive no rent for the water taken from these tanks, I am, like other landholders and lakhraj-dars, remunerated in another way, *i. e.*, by the receipt of higher rents from the ryots whose lands are benefited by the tank than from those who have no such convenience. The facility thus afforded to cultivation is pretty well understood by the ryots, and lands are designated 1st, 2nd, and 3rd class paddy land, according to their position in reference to the irrigating tanks.

When water for irrigation purposes will be supplied by a State Canal, and a separate fee charged on the ryots for the same, the question will naturally arise as to how claims for adjustment of rents by the zemindars will be decided. The landholders might justly object if they are debarred from enhancing the rent for increased produce of the soil, and the ryots might complain if they are made to pay water-rates as well as the *nirick* rate of rent. This is a difficult question, and one susceptible of elaborate argument on either side. If the water-rates be, however, reckoned as an item in the costs of cultivation, and the zemindars be allowed to adjust the rent according to the steady improvement of the land, I think neither party will have cause to grumble. This question might, however, be left for ulterior settlement, when the experience of four or five years will enable the parties to discuss it on a more definite basis than at present.

From W. E. WARD, Esq., Officiating Collector of Burdwan, to the Commissioner of the Burdwan Division,—(dated 26th December 1869.)

In reply to your No. 388T. dated 7th September last, with enclosures, calling for a report of the anticipated advantages of the Damoodah and Hooghly Canal, I have the honor to report as follows.

2. The lands of this district may be regarded as divided into two grand classes—*Sona* and *Sali*. *Sona* lands are those which are situated nearest to a village; *Sali* lands are those which are more remote. As the villages of Bengal are all built on the high lands of the country, *Sona* lands are necessarily high lands, and will not retain water; whereas *Sali* lands are comparatively low and retain water more or less according as they are low or high.

3. *Sona* lands are divided in this district into four classes, viz., *Sona* 1st class, *Sona* 2nd class, and so on. A similar division is made with respect to *Sali* lands. The rate per beegah paid for *Sona* lands varies from Rupees 2 to Rupees 5 or Rupees 6; and for *Sali* lands, from 12 annas to Rupees 2-8, or Rupees 3, a beegah.

4. *Sona* lands produce generally two crops in the year, viz., *amun* paddy, and a cold weather crop. *Sali*, as a general rule, (to which, however, there are exceptions) produces only one crop, viz., the *amun* or *hoymontie* paddy.

5. The produce per beegah of every crop sown, whether it be sown on *Sona* or on *Sali* land, varies, of course, with the fertility of the land; and one of the first points to which I directed my enquiries was to ascertain whether the difference in fertility between two classes of *Sali*, or between two classes of *Sona* land, arose from difference of soil or from difference of level only. This is an important point to settle before considering the anticipated advantages of irrigation, and the probability of the ryots taking water.

6. As regards the *Sali* lands, I find there can be no doubt that the difference in class arises only from a difference of level. Those lands which are lowest, and which are capable of retaining much water, are called 1st class *Sali* lands; those that are highest and throw off water quickly are called 4th class *Sali*. As a rule there is no difference of soil between one class of *Sali* land and another, except that which may be caused by artificial manuring. The capacity of *Sali* land to retain water alone determines its class.*

* NOTE.—The *Jol Sali* lands form an exception to this general rule. These are the very low rice lands which lie along the natural drainage channels of the country, and which, when the rains fall, receive all the fertilizing scourings of the villages situated on high lands through which those channels pass.

We thus arrive at a very important fact, which has been admitted by nearly every ryot of this district whom I have questioned on the subject, that it is possible, by increasing water-supply, to convert 3rd class *Sali* land into 1st class, or, in other words, to increase the profits of a ryot holding 3rd class *Sali* lands by nearly Rupees 5 a beegah *per annum*.† Fourth class *Sali* might similarly

† *Vide* estimate of annual profit from *amun* sown (1) on 1st class and (2) on 3rd class *Sali*, as given in the Statement of Crops subjoined to this report.

be converted into 2nd class. I do not think we could go so far as to expect the canal to convert the worst class *Sali* into 1st class, because these lands are so very high that the water

would run off, or percolate, to the low lands very rapidly, and the demand for water on these lands, even supposing it could be met by the canal, would be so great that there would be danger of flooding the low lands, and moreover much water would be wasted.

7. It has been stated by some that there is a difference of soil between the several classes of *Sali*, but careful enquiry has removed in my mind all doubt on this point. The superior classes of *Sali* are, I certainly find, often more manured than the inferior classes, but the reason for this is clear. If a ryot can satisfy himself that as much water will be supplied to him as he wants he will manure his land. If he cannot get water he will not waste manure.

8. With respect to *Sona* lands the case is much the same; accessibility to tank water, or what is, as a general rule, the same thing, proximity to a village, and the amount of artificial manuring to which the lands have been subjected in past years alone determines its class.

9. Nor can it be said even that there is any natural distinction between the soils of *Sona* and *Sali* lands. This distinction between these two grand classes of land arises also, I think, solely out of a difference of level and a difference in the amount of artificial manure given to each class of land. All lands near to villages are *Sona* lands, simply because they are near, and are, therefore, high and close to village tanks, and because they receive the greater share of the village manure available. If there were any natural distinction in soil between *Sona* and *Sali* lands, how is it that every village has been built exactly in the centre of *Sona* land. I do not think it can be said that the sites of villages were originally selected with a view to the qualities of the land to be comprised in each village. Had this been the case, we must have expected to find many villages situated in low lands. The fact is that all villages have, for obvious reasons, been built on high lands, and it is the existence of the village which has alone made the soil of the *Sona* land what it is.

10. I have entered thus fully into this matter, because another point which in my enquiries I have sought to determine is whether it is not possible to convert *Sali* lands into *Sona*, in the same way as I have found it possible to convert one class of *Sali* into *Sali* of a superior class. *Sona* land, as I have stated, produces generally two crops in the year. If

canal water supplied, as often as required is capable of converting *Sali* land into *Sona*, it is needless for me to say how great will be the boon conferred upon the ryots of this district.

11. Now, as a fact, I find that there are *Sali* lands in this district which do grow a double crop, but only those lands have been selected which are accessible to artificial irrigation. The area of lands of this class growing a double crop is necessarily very small, for tanks at a distance from villages, and outside the limit of *Sona* lands, are rarely seen.

12. The main objection to sowing a *rubbee* crop on *Sali* land is that *amun* paddy, being, as a rule, the only crop cultivated on those lands, is reaped too late to allow of land being got ready for a sowing in season of any *rubbee* crop; and moreover, in the lower, or first class *Sali* lands, water often remains on land after the *amun* paddy has been cut, and cannot easily be drained off. The land, therefore, is not in a fit state to receive seed.

13. This objection in the case of low *Sali* lands may be left out of consideration. I do not think that *Sali* 1st class lands constitute more than $\frac{1}{3}$ th of the entire *Sali* lands in the district; 3rd class *Sali* may be estimated at about $\frac{2}{3}$ ths, and the other two classes at $\frac{2}{3}$ ths each. The question, therefore, is whether, reckoning the *Sali* lands as constituting $\frac{2}{3}$ rds of the whole district, it would not be possible, by the introduction of canal water, to make 3rd and 4th class *Sali* lands, i. e., $\frac{5}{12}$ ths, or nearly one-half of the whole district, produce a double crop instead of a single one as it now does.

14. If the lateness of the year at which the *amun* crop is cut is an insuperable obstacle to the sowing of any cold weather crop on the same land—and I am not altogether sure that it is so—there are two other ways in which a double crop might be reaped from these lands. The first is by not growing *amun* at all upon them, but only *aous*, which is reaped in August and September, and the second is by growing a different kind of *amun*, viz., that known as “early *amun*” on the *Sali* lands alluded to. This course is the one which I think would be adopted, because *amun* is more profitable than *aous*. *Aous* paddy is cheaper than *amun*, and the straw is not fit to sell. *Aous* is also very indigestible and unwholesome, and therefore not in demand, except amongst the very poor classes.

15. I need not discuss this question further. The above remarks will suffice, perhaps, to show what an inestimable boon the canal water will bestow upon the ryots of this district. From the many ryots with whom I have spoken on the subject, between this and Raneegunge, I can say that, excepting the very poor and least intelligent classes, the ryots themselves are fully alive to the benefits they will derive, and, with few exceptions, are quite willing to pay for those benefits. The complaint of the agricultural classes, between this and Raneegunge, appears to be universal that the rainfall is very deficient. A full crop in this district rarely occurs, perhaps once only in six years. The out-turn of the current year may be estimated at not more than 12 annas.

16. As regards the rate per beegah the ryots would pay for water, I should say in this district they would willingly give for rice lands the rent of which was Rupees 3, 8 annas a beegah, and less in proportion for lands bearing a lower rent. In the case of *rubbee* crops the rate might be from 4 annas to 3 Rupees a beegah, according to the estimated profit per beegah from the crop which is being grown. Subjoined to this report is a statement which I have drawn up of the principal crops sown in this district, and the profits per beegah from each as estimated by me after careful enquiry. This statement may also serve to elucidate many of the remarks made above.

17. I may state that, during my enquiries on this subject, I was often questioned by the ryots as to whether the canal water would bring with it any silt in suspension. The more silt that the canal water can be made to carry with it the higher will be the rate per beegah which the ryots will pay for the water. The fertilizing effects of river water are well known, and no ryot will irrigate his land with tank water if he can get river water. I think also I may go as far as to say that a ryot would sooner pay for river water with silt in it than take tank water for nothing. I fear that during the dry weather the canal water cannot be expected to carry much silt in suspension. However this may be, I think every endeavour should be made to get the water to carry as much silt with it as possible, both in the dry and rainy seasons. This will get rid of another objection which I have heard urged

to the cultivation of *Sali* lands with two crops, viz., that, as a double crop cannot be successfully grown on any land unless well manured, *Sali* lands cannot be expected to produce two crops; *firstly*, because the amount of manure available in a village is not, as a rule, sufficient to manure all the village lands; and *secondly*, even if manure were available, the ryots would not find it worth their while to convey manure to such a distance from their villages. I do not attach any weight to this objection, but admitting it to hold good, the flooding of the *Sali* lands with water bearing silt in suspension will dispense with the necessity of artificially manuring the *Sali* lands, if not altogether, at least to a very great extent.

18. When I say that the ryots will pay so much per beegah for canal water, it must of course be understood that they will not all come forward at once. They will undoubtedly hang back for a time; but if the rates are fixed and canal water denied to any one except at those rates, the better class of ryots will not be long in coming forward, and their less intelligent brethren, on seeing the effect of canal water, will soon follow in their wake.

19. Without even going into the question at all as to whether *Sali* lands can or cannot be made to produce two crops in the year, and taking only a broad view of the matter, I may say that I have not yet met a single ryot in this district who has not admitted to me that, if his *Sali* lands, of whatever class, (except, perhaps, the 1st class *Sali* which, as a rule, retains as much water as it wants,) had as much water given to them in season as they required, the weight of the paddy produce per beegah would be half as much again. This being so, it is not possible to conceive that any ryot would be so bigoted or blind to his own interests as to refuse to pay for canal water.

20. As regards the system of irrigation now practised in this district, I find that artificial irrigation is practised to a very small extent. Tank irrigation extends over a very limited area. All the tanks of a village are not available for irrigation. There are bathing tanks and irrigation tanks. From the latter water is conveyed by small channels

to distances varying in different villages from 500 yards to half a mile. Irrigation also takes place from some of the small streams which intersect the district, such as the Singarun and Tumlah Rivers, and the Khurrea, Banka and Konoor streams. Irrigation from these streams and rivers requires much labor. Bunds have to be thrown across and the water lifted to a considerable height, in consequence of the high embankments. If, as Captain Garnault gives me to understand, the only labor required from a ryot when watering his fields with canal water will be to excavate a small channel from the nearest point of a canal distributary to his field, there can be little doubt that the present system of irrigation from rivers and streams, if not also tank irrigation, will speedily be abandoned by the ryots.

21. I notice that Colonel Anderson, in the 37th paragraph of his note of the 31st of May last, states that the rice crops must already be raised by irrigation. I do not know upon what facts this statement is based. Possibly the statement made by Mr. Lockwood, the Collector of Hooghly, that irrigation is carried on generally throughout the Hooghly district, and that the area irrigated may be considered as nearly equal to the area of the whole district, may have been Colonel Anderson's authority. I can certainly, however, say that, whatever may be the case in Hooghly, the area of rice land watered by artificial irrigation in the Burdwan district bears a very small proportion indeed to the total area of rice lands cultivated.

22. The Government of India and Colonel Anderson have also raised the question as to whether irrigation from the Damoodah by flooding the low lands, which have already as much water as they require, may not prove absolutely injurious unless the ryots can be induced to give up the present system of irrigation. This is perhaps a question which the Superintendent of Works can better reply to than I can. As stated above, however, I have little doubt that, after the completion of the canal with its distributaries, the ryots will soon abandon their present system. Then again, when it is borne in mind, as the Superintendent of Works informs me that the general fall of the country in this district is from the bed of the Damoodah about 4 feet in the mile, there is little fear of water stagnating in the low lands.

23. I observe that, in the correspondence published in the *Gazette of India* of the 19th August last, and also in the Bengal Government's letter forwarded with your letter under reply, allusion is made to the combining of a system of irrigation with that of drainage. The Government, however, are probably aware that, whatever may be the case in the Hooghly district, the Burdwan district requires little or no drainage. The canal and its distributaries will, of course, not serve as drainage channels, as these will run along the high lands of the country; the distributaries however, Captain Garnault informs me, will be ultimately led into the drainage channels, the Irrigation Department, by so doing, undertaking to drain off all water which may be artificially supplied from the Damoodah.

24. Another question which has been raised is the difficulty which may arise in dealing with proprietary rights, with regard to water supply, and whether, if any such rights exist, the difficulties are so insuperable, as that no satisfactory arrangements for their removal can be come to with the proprietors. I expect this is a question which has reference more to the Hooghly than to the Burdwan district. The system, however, of throwing bunds across rivers and streams, as alluded to in paragraphs 38 and 39 of Colonel Anderson's note, *does* prevail to some extent in this district. It prevails, I am told, on the Singarun and Toondla Rivers, and on the Khurrea, Konoor, and Banka, and perhaps some other streams. The water from the distributaries will, as before stated, ultimately fall into these streams, and, as Colonel Anderson observes, the canal water, thus accumulated in these streams, may be used by the ryots, and it will not be in the power of the Irrigation Department to compel them to pay for its use.

25. I do not myself think that the Government has any occasion to think very seriously of this question. Colonel Anderson says that it will be difficult to prove what particular water irrigates a field—canal water thus banded in streams, or canal water proper. I think, however, the Irrigation Department could, without difficulty, make arrangements for ascertaining this in every case, and, even if they cannot, the

area which these streams will be able to irrigate will, I think, be very small in comparison with what the canal and its distributaries can irrigate, particularly when it is borne in mind that comparatively the streams alluded to run along the low lands of the district, whereas the canal and its distributaries run along the highest lands.

26. Prescriptive rights to throw bunds across streams undoubtedly do exist, and, I believe, have been upheld by Courts, but I think it would be waste of time to speculate what the people will do hereafter, or to attempt now to come to any arrangements with proprietors. Should the Government afterwards find that the *bund* system still continues in force, and that their interests are being injured by the amount of canal water which the people are able by this system to utilize for irrigation purposes free of charge, special legislation must be resorted to; it would be futile to attempt to make any private arrangements with the proprietors. I do not, however, anticipate any difficulties under this head. The bund system owes its origin to want of water, and so, I think, a copious supply of water will suffice to destroy that system. The area capable of being irrigated from streams is, as I have said before, small, and the labor of lifting the water over the high embankments is such as the ryots would gladly pay something to avoid.

27. I have now reported upon all the points raised by Government with respect to this canal. I only wish to add, with reference to the reply given by my predecessor to the sixth question proposed by Captain Garnault, as given at page 1105 of the *Gazette of India*, dated 21st August last, that *Sali* 1st class land, excepting those which already get as much water as they require, will, if irrigated in season by canal water, produce certainly 25 maunds of paddy *per beegah* and, in some cases, more. It is not water alone which effects this, but a ryot, as before stated, will, if he knows that he can get as much water as he likes, and when he likes, take more pains to manure his land and render it as productive as possible. Water and manure combined will increase the produce *per beegah* half as much again; some say will even double it.


Statement of Crops grown in the Burdwan District.

(300)

Name of Crops sown.	Date of sowing.	Date of cutting.	Estimated profit per beegah.	
Aous (Kelesh)	... Middle of Jeth, if there be rain, i. e., about 30th May.	End of Bhadro, or beginning of Assin, (15th September).	Rs. 5-8 or Rs. 3, if half the rent of the land, i. e., Rs. 2-8 be debited to this crop.	Requires more water than <i>aous</i> proper, but less than <i>amun</i> . Gross produce per beegah about the same as <i>amun</i> , and value of produce about same as <i>aous proper</i> .
Aous Proper	... End of Bysack, (15th May).	End of Shrabon, or beginning of Bhadro, (15th August).	Rs. 5-10 or Rs. 2-2, supposing half the rent of the land, i. e., Rs. 2-8, be debited to the profits derived from <i>aous</i> , and the other half to the profits derived from the second crop.	Requires little water. Average 1st class <i>Sona</i> lands produce about 15 maunds a beegah, which, valued at 1½ maunds the rupee, gives, after deducting Rupees 3 for cost of cultivation and cutting, &c., a profit of Rupees 5-10. Requires more water than the <i>aous</i> crop, but less than <i>amun</i> .
Aous (Neali)	... Sown at same time as <i>kelesh aous</i> .	A fortnight after <i>kelesh aous</i> is reaped.	Same as <i>kelesh aous</i> ..	Same remarks as on <i>kelesh aous</i> . Neither <i>kelesh</i> nor <i>neali</i> are so common in this district as the <i>aous proper</i> .
Mustared (Surso)	... In Kartick, or beginning of October, after the <i>aous</i> has been reaped, and the land re-ploughed and manured.	In Magh, or about end of January.		Requires little water.
Barley	... Ditto	Ditto		Ditto.

Wheat	...	Ditto	...	Ditto	...	Excepting peas, which give a profit of from Rs. 10 to Rs. 15 a beegah; the profit derived from these crops is small, and may be put down on the average at Rs. 5 a beegah.	Requires little water.
Linseed or } This is or common } Mashiná Flax.	...	Ditto	...	Ditto	...		Requires scarcely any water at all.
Pulses.	Beri Kalái ...	Ditto	...	End of Pous, i. e., about 15th January.	...		Ditto.
	Mussoor ...	Ditto	...	In Magh, or about end of January.	...		Ditto.
	Gram ...	Ditto	...	Ditto	...		Ditto.
	Kapási Moogh	Ditto	...	Same time as beri kalái	...		A species of Moogh which is sown along with cotton; requires scarcely any water. Requires a little water.
	Peas ...	Ditto	...	In Magh, or about end of January.	...		
Cotton	...	In Kartick or beginning of October, after the rains has been reaped and the land re-ploughed and manured.	...	The picking season is from the middle of By-sack to the middle of Assar, i. e., during May and June.	...	About Rs. 8	This crop is sown only on Dó lands, a very superior class of <i>Sona</i> lying close to a village, and to which water and manure is easily accessible. The cotton cultivation in this district is very small and not popular, owing to the amount of labour required and the small profits which result. The cotton grown is all consumed within the district, so that it is difficult to estimate accurately the profit per beegah.
	Amun or hoymontie paddy	In Assar, if there be rain, i. e., about 15th June.	...	In Aughran and Pous, from 15th November to 15th December.	...	Rs. 16-8	The crop requires much water. This crop, of course, requires much water, the more the better, although, according to the best

Name of Crops sown.	Date of sowing.	Date of cutting.	Estimated profit per beegah.	
				<p>authorities, the water should not cover more than three-fourths of the stalk. <i>Amun</i> is sown on <i>Sali</i> lands only; never on <i>Sona</i>. The profits shown in column 4 are on a beegah of average 1st class <i>Sali</i> lands, and have been calculated as follows:—</p> <p style="text-align: center;">Rs. As. P.</p> <p>Gross produce of paddy per beegah 15 mds. @ $1\frac{1}{4}$ mds. per rupee ... 10 0 0 Ditto of straw, 15 pons, @ 6 pons the rupee ... 2 8 0 <hr/> 12 8 0</p> <p>Deduct cost of cultivation and reaping and storing ... Rs. 3 Rent ... " 3 ... 6 0 0 <hr/> Net profit ... 6 8 0*</p> <p>The profit derived from this crop, as grown on <i>Sali</i> 3rd-class, of which the greater portion of this district is composed, may be cultivated as follows:—</p>

Name of Crops sown.	Date of sowing.	Date of cutting.	Estimated profit per beegah.	
Arhar (a species of pulse)	In Assar or June ...	In Chyet, (March, April.)	Profit very small in this district.	This crop is sown on <i>Sona dāngā</i> lands, i. e., very high lands of the worst <i>Sona</i> class, where <i>aous</i> is never sown; it is also sown in the margin of sugar-cane lands. A beegah of land sown with <i>arhar</i> does not admit of any other crop within the year after the <i>arhar</i> has been reaped. Very little <i>arhar</i> is sown in this district.
Teorā kalāi, or khesāree (a species of pulse.)	In Kartick, or about 15th October.	In Magh, (January, February.)	Not very profitable ...	This crop is sown on low <i>Sali</i> lands which are sufficiently moist when the sowing season arrives. The seed is sown before the <i>amun</i> rice is cut, and when the <i>amun</i> is cut, the <i>khesāree</i> is left standing about half a foot or foot high.
Potato ...	In Assin, (September, October).	<i>Vegetables.</i> From Aughran to Fallow, (between November and February.)	Rupees 45	Requires much water. Is sown on <i>Sona</i> lands after the <i>aous</i> has been cut. This crop is cultivated much in the eastern part of the district and at Cutwa, but scarcely at all in the western part of the district.
Shakar-kand  lu, or Sweet Potato.	In Jeth generally, (May, June), but also at any time from Jeth to Kartick, (October).	Ditto	... 15	Requires little water; sown on <i>Sona</i> lands, much cultivated. If sown in Kartick is sown on same land as <i>aous</i> and after the <i>aous</i> is reaped.

Shánk Alu	...	In Assar, (June, July).	Ditto	...	"	20	...	Requires little water ; is sown on Sona lands ; not cultivated to a very great extent. Does not admit of aous being sown on the same land.
Begoon	...	Ditto	...	Bhádros to Chyet, (between August and March).	"	30	...	This vegetable is more cultivated than any other. No other crop can be sown on the same land within the year. Sown on Sona lands.
Moolá, (Radish)	...	Ditto	...	Kartick to Pous, (between October and December).	"	15	...	Scarcely any water necessary ; much cultivated ; sown on Sona lands.
Kochoo	...	Bysack, (April)	...	Assar to Aughran, (from June to November).	"	25	...	Requires much water ; sown on Sona lands ; does not admit of aous being sown on same land.
Onion	...	Assin to Kartick, (September and October).	...	Aughran to Magh, (November to January).	"	30	...	Requires much water ; is much cultivated ; is grown on Sona lands.
Roshoon (Garlic)	...	Ditto	...	Pous	"	10	...	Not much sown. Requires much water. Sown on Sona lands.
Ahdá (Ginger)	...	Bysack and Jeth, (April and May).	...	Assin to Magh, (September to January).	"	30	...	Much sown on Sona lands. Requires little water.

Name of Crops sown.	Date of sowing.	Date of cutting.	Estimated profit per beegah.	
Potol	Aughran, (November)	Falgon to Assar, (February to June).	Rupees 20	... Much sown on very high Sona lands. Requires water occasionally. Does not admit of any other crop being sown on same land.
Láu, (the long Gourd or Pumpkin).	Kartick, (October)	Falgon to Bysack, (February to April).	5	Ditto ditto.
Uchohe	Ditto	Falgon to Jeth, (February to May)	10	Ditto ditto.
Kheurá or Kheruyá, (a kind of Kidney Bean).	Ditto	Ditto	10	Ditto ditto.
Turnooj, (Water-melon)	Ditto	Ditto	8	Ditto, but not much cultivated.
Kamrá, (a species of Gourd)	Assar, (June)	Magh, (January)	10	Ditto much cultivated.
Káukur, (a species of Cucumber).	Magh, (January)	Bysack to Jeth, (April and May).	5	Ditto ditto.
Shoshá (Cucumber)	Ditto	Ditto	5	Ditto ditto.
Torai	Kartick (after the aous has been reaped).	Chyet to Assar	20	Much cultivated on Sona lands.

W. E. WARD,
Officiating Collector.

From Commissioner of the Burdwan Division,—(dated 25th June 1870.)

Copy of the following forwarded to the Secretary to the Government of Bengal, in continuation of this Office No. 1T. of the 3rd January last, with the request that he will cause the proposed corrections to be made on the copies of the printed enclosures alluded to by the Collector.

From Collector of Burdwan, to Commissioner of the Burdwan Division,
—(dated 16th June 1870.)

In the statement submitted with this Office No. 566 dated 24th December 1869, reporting on the anticipated advantages to be derived by the Damoodah and Hooghly Canal, I estimated the net profits from Sali 3rd class land to be as follows :—

	Rs.	As.	P.	Rs.	As.	P.
Gross produce per beegah, 8 maunds, at 1½ maunds the Rupee ...				5	5	0
Deduct rent ...	1	4	0			
Labor (if employed) in cultivating and storing... ..	2	8	0			
				3	12	0
Nett profit ...				1	9	0

2. For the above estimate should be substituted the following :—

	Rs.	As.	P.	Rs.	As.	P.
Gross produce per beegah, 8 maunds, at 1½ maunds the Rupee ...				5	5	0
Ditto of straw, 8 pons, at 6 pons the Rupee				1	5	0
Deduct rent ...	1	4	0			
Labor (if employed) in cultivating and storing, &c.	2	8	0			
				3	12	0
Nett profit ...				2	14	0

3. It will be observed that I omitted to include in the ryot's gross profits what he would realize by the sale of straw.

4. As the error is a material one affecting the question of the water-rate to be levied from ryots who hold lands of this class, I request the favor of your sending a copy of this letter to Government, in order that the necessary corrections in the printed copies of the enclosure of my letter above alluded to may be made.

From the Government of India, to the Government of Bengal,—(10th June 1870.)

I am directed to acknowledge receipt of your letter No. 246I. dated 7th April 1870, with reports and revised plans and estimates of the proposed canal from the Damoodah to the Hoogly ; and in reply to state that they will be forwarded for the consideration and orders of the Secretary of State.

2. Meanwhile His Excellency the Governor General in Council desires that the expenditure on preliminary operations at the head works may be suspended.

3. I am to request that the attention of His Honor the Lieutenant-Governor may be drawn to the Secretary of State's despatch No. 98 dated 12th October 1869, in which a hope is expressed that no heavy expense will be incurred until the project is fully matured. Now, while the estimates as revised are full and complete, and in every way creditable to the Officer who prepared them, His Excellency the Governor General in Council, notwithstanding the strong recommendation in favor of the scheme of His Honor the Lieutenant-Governor and of various Officers who have been consulted, is not satisfied that the Government in carrying it out would be secured from financial loss, owing to there being no certainty that the people would take the canal water regularly. And, moreover, the possible effect of the recent discovery of coal at Midnapore has also to be considered. Should it result in a coal field equal to that at Raneegunge being found at that place, or in the neighbourhood, one of the principal objects to be gained by the formation of the proposed canal would no longer exist, since

the Midnapore Canal, which is likely to be opened within the next two years, would furnish a much shorter route for the conveyance of coal to Calcutta.

4. Under these circumstances, His Excellency the Governor General in Council is unwilling to incur any further expenditure on the work without the express authority of the Secretary of State.

From the Government of India, to the Government of Bengal,—(dated 10th June 1870.)

In continuation of Public Works Department letter No. 248I. dated the 10th instant, I am directed to forward, for the information of the Hon'ble the Lieutenant-Governor, the accompanying extract from a Note by the Officiating Inspector-General of Irrigation, and copy of a Despatch addressed to the Secretary of State on the Damoodah Canal Project.

Extract of a Note by the Inspector-General of Irrigation.

In paragraph 3 of the letter from the Government of Bengal, it is explained that the Lieutenant-Governor has caused the terminus of the canal to be changed from the site first proposed to Trebenee Ghaut, in deference to the opinion expressed by His Excellency the Governor General in Council, but that he believes that the continuation of the Canal to Calcutta will be required eventually, and that it is certain that the longer it is delayed the more expensive will the purchase of the necessary land be found. This must be quite true, but I may remark that the suggestion to make Trebenee Ghaut the terminus did not originate with the Government of India, but with the Chief Engineer, who, in his first report, paragraph 12, states that it may be advisable not to carry the canal so far even as Serampore at first, but to lead it instead to the Hooghly at Trebenee Ghaut; and he adds that the connection with the Hooghly might then be effected a little more quickly, and the branch to Trebenee Ghaut would, even after the extension to Calcutta, be still always useful.

The proposed arrangements for the distributaries appear to me to be satisfactory. A list of the distributaries, the supply of each, and the

area each will be capable of irrigating, is furnished in Captain Garnault's report ; and as the alignments have been determined from actual cross sections of the country, no material alteration ought to be necessary in carrying them out. On the explanation given, the estimate of cost of the distributaries may, I think, also be accepted as approximately correct.

A summary of what has been done on Reservoir exploration is given by Captain Garnault in Section II. of his report, which is likely to be useful hereafter ; but as the present project and the proposed Reservoirs may be considered separately, and may each be judged on its own merits, it is quite unnecessary to postpone a final decision about the canal until the economical practicability of constructing Reservoirs shall have been determined.

The slope and dimensions of the canal have been altered in the manner suggested in my Note on the original estimate, though the Chief Engineer as well as Captain Garnault still consider the former arrangement to be the best. On a technical question of this kind, I should be sorry if an arrangement were forced on the Chief Engineer against his own convictions, unless a positive advantage could be clearly proved in its favor. And in this case the suggestion was only offered for the consideration of the Bengal Government: its adoption was not imperatively called for. Doubtless, Colonel Rundall's opinion should carry great weight, and since his own experience has not led him to attach much importance to the disposal of silt, since he has not found its removal on canals, similar to that under consideration, a matter of much practical difficulty or expense, I should be glad if he were allowed to follow his own plan, on his simple assurance that the Damoodah Canal would be under similar conditions, as regards silt, to the other canals on which he has been engaged. But the facts given in the Chief Engineer's own report seemed to lead to a different conclusion. If, as he stated, the muddy water of the Damoodah would quickly stanch the embankments and fill in the hollows in the bed to a uniform level, it must be evident that the process would not stop there unless the velocity were to be kept up to a uniform standard in the different reaches, which, however, the designs did not provide for. Allowing that Captain Garnault's estimate of the possible deposit of silt and the cost of removing it annually (Rupees 40,000) is a highly

exaggerated one, and that one-third or one-fourth of the amount stated would more nearly represent the actual silting, still it must evidently be very desirable to keep silt deposits out of the main channel altogether if possible, since their clearance could only be effected by the expensive process of dredging or by a closure of the canal. On the other hand, the report of Captain Garnault and of the Revenue Officers contain ample evidence of the importance attached by the cultivators to obtaining water for irrigation loaded with the fertilizing mud brought down by the freshes of the Damoodah. Captain Garnault states that it is not certain that the income derived from the produce of the whole land on account of the heavier produce of the land fertilized by the Damoodah deposits is not as great now as it was before the river embankments were removed, though the land is otherwise liable to injury from excessive inundation. And the Collector of Burdwan thinks he may go so far as to say that a ryot would sooner pay for river water with silt in it than take tank water for nothing; and he urges that every endeavour should be made to carry as much silt with it as possible, both in the dry and rainy seasons. Thus it would appear to me very desirable, both on engineering and financial grounds, to prevent silt from accumulating in the Main Canal by keeping the velocity of the stream, as closely as circumstances will permit, to the standard which will allow of its being carried forward in suspension to the minor distributive channels and by means of them to the fields.

The Chief Engineer deprecates the reduction of the width of the canal to a minimum of 40 feet at bed and 60 feet at surface. The Government of India, however, approved of arrangement being made for subsequent enlargement to a width of 55 feet at bed and 75 feet at surface. What the Chief Engineer recommends is, that provision may be made for future enlargement up to 90 feet at surface or 15 feet more than the above. The width of the Locks is however retained at 17 feet and length at 100 feet, instead of the dimensions proposed by the Government of India, and, indeed, ordered as a standard for first class canals, *viz.*, 20 feet wide by 150 feet long. The reasons for preferring a smaller Lock are given in paragraphs 7 and 8 of Colonel Rundall's note.

It is proposed to add a second Lock hereafter, if further accommodation for traffic is required, and this might be built, it is said, without

closure of the canal, which would no doubt be a great advantage. Two Locks, 100 feet by 17 feet, would, however, cost more than a single Lock 150 by 20, by £50,000 for the whole canal, and they would, moreover, require two establishments instead of one.

A quotation is given from an American pamphlet in support of the above views regarding the width of the channel. It would appear, however, that, so far as this example offers any proof in favor of a wide channel, it is equally conclusive in favor of large Locks. The American Engineer decided on designing his canal for the employment of steam power, on giving it a width at bottom of 70 feet and at top of 80 feet, and the Locks a length of 160 feet and width of 35 feet. The width of the channel was thus sufficient to allow of two steamers passing each other. As the Lock recommended by the Chief Engineer for the Damoodah Canal is only 17 feet in the clear, while the Government of India authorized provision being made for a final width of channel of 55 feet as a minimum for the bed, I conclude that the largest-sized boats that could pass through the Locks could ply with as much convenience in a channel of that width as the steamers in the other case. However, Colonel Rundall only asks for a width of 15 feet more than the Government of India allowed, and as the recommendation of His Honor the Lieutenant-Governor is given in its favor, I think it may be allowed, especially as the increase need not be given till proved by experience to be desirable or necessary, and as therefore the only extra expense which would be entailed in the first instance would be in the purchase of the above additional width of land.

As regards the Locks, however, I am of opinion that they should not be less than 150 feet by 20 feet. The larger the Locks are the more economically can steamers carrying their own freight be worked, and it seems necessary to make some provision at all events for the possibility of steam-power being introduced on this canal.

I am also of opinion that the great number of Locks on the proposed canal, 20, of which three are double Locks, would be an insuperable objection to the employment of steam for the haulage of cargo boats. Captain Garnault seems to have mistaken steam carriage for steam haulage, and he should have explained that, in nearly all the instances he has given of the employment of steam power on the English or Scotch

canals, it has been either on single barges or along reaches of canal without Locks.

Thus, it is said in the proceedings to which Captain Garnault refers that on the Severn a new Lock had been constructed with a large basin attached, which allowed of a steam tug and train of nine vessels at the same time: engines on board the cargo vessel, instead of towing with detached tug vessels, are however recommended.

With regard to the Gloucester and Berkeley Canal, instanced by Captain Garnault, Mr. Leader Williams showed what had been done with steam along a length of 16 miles *without Locks*. He adds that on the Weaver a length of 24 miles was divided into eight pounds, some as much as 6 miles, others only half that distance apart, that steam tugs had been tried upon them without success; that although the Locks (100 by 23) had been doubled, the delay with steam tugs towing several barges was so serious and so interfered with the traffic that the plan had to be given up, and that to do away with this difficulty a third Lock, 200 feet long by 40 feet wide, to allow of its holding a tug and three barges, was about to be added for each pound. Again, on the Forth and Clyde navigation, though Captain Garnault speaks of steam haulage being used with great success, the fact is that it is not haulage at all but only steam carriage, the barges being fitted with a small steam engine and carrying their own cargo.

On the Ashby-de-la-Zouche Canal, Mr. Pole says, some coal-owners thinking that it offered a good opportunity for the use of steam haulage (there being no Lock for a length of 30 miles) proposed to convey their coals in this way.

On the Regents Canal (another of Captain Garnault's examples) there was a 2-mile level at the head of the canal, on which portion alone steam had been employed.

It is said that on the Grand Junction Canal, where there were many Locks, great delay and loss must necessarily arise, and that on the Aire and Calder navigation the Company were devoting considerable expenditure to lengthen the Locks.

Finally, Mr. Beardmore, who will be acknowledged as a high authority, gives his opinion on the matter in the following terms;—

“Steam navigation on the smaller Canals was full of difficulties... As a rule, the inland canals in this country might be taken as having a width at the top of about 45 feet and a depth not exceeding 5 feet, though generally not more than 4 feet, with a vast number of Locks in their course, frequently only admitting boats 7 feet 6 inches in width, and 70 feet in length. If anything like trains with steam tugs were attempted, the loss of time in passing each vessel separately through the Locks was so great as practically to prevent the successful adoption of that mode of transit. From this delay and the difficulties offered by the resistance in the restricted waterway, *all attempts to work by steam trains in the canals in this country had failed.* Steam trains had been tried on the Shropshire Union Canal with sufficient capital at command; but the experiment was a failure from the difficulties encountered in passing the Locks, and getting through the shoal sections of the canal. The same causes had operated against the success of steam towing on the Kennet and Avon, the Leeds and Liverpool, and many other canals.

* *Vide also The Artizan for March 1870, pages 49 and 54.*

The Grand Junction Canal Company alone still worked a portion of their traffic by steam traction.”*

I think it will be admitted that the above is pretty conclusive evidence against the employment of steam haulage on a canal on which there are many Locks; and when Captain Garnault stated that the number of Locks on the Damoodah Canal is nothing compared to the number on many of the canals in England on which steam power has quite superseded the use of horses, he should, in common fairness, have pointed out the drawbacks in the way of the employment of steam-power for towing, to which canals under such conditions must be subject.

Captain Garnault, in compliance with a requisition from the Government of India, has computed the probable cost of haulage on the canal, and has compared it with the Railway rates. The only weak point in his figures is the time he allows for a boat to travel up and down between Raneegunge and Calcutta, which appears to me to be considerably under-estimated. Colonel Rundall could have obtained more accurate information from actual observation on the Kendrapara Canal in Cuttack or on the Midnapore Canal which is open from

Oolooberiah to Panchkoorah. The cost of simple haulage on the canal is estimated by Captain Garnault at 1·06 pies per ton per mile, while that on the Railway is supposed by him to be from 3 to 4 pies. The comparison is not strictly correct. According to the best information available in the Railway Branch, the cost of haulage per ton of goods on the East Indian Railway amounts, it is true, to $\frac{1}{8}$ th of a pie per maund per mile, or about $3\frac{1}{2}$ pies per ton per mile; but this does not simply represent the cost of locomotive power, but includes the proportional charge for engineering, traffic, and general expenses as well. The above rate of $3\frac{1}{2}$ pies corresponds very fairly with the actual expenses in working the Madras Railway, the only extensive line on which detailed accounts of the mileage of goods between different Stations are prepared. The accounts of that Railway, which are collated half-yearly, distribute the whole of the revenue expenditure over the different items of traffic in proportion to the gross weight of each moved over one mile, and it is probable that a very high degree of accuracy is thus attained. The following are the results for the last five half-years for which the Revenue accounts have been received :—

	South-West Line.		North-West Line.	
	Average load on Goods wagon.	Expenditure per vehicle per mile.	Average load on Goods wagon.	Expenditure per vehicle per mile.
1st half 1867 ...	3·241 tons.	9·88 pies.	2·467 tons.	11·60 pies.
2nd „ „ ...	2·599 „	10·29 „	2·142 „	10·82 „
1st „ 1868 ...	3·093 „	12·38 „	3·222 „	11·12 „
2nd „ „ ...	3·041 „	12·07 „	3·133 „	16·36 „
1st „ 1869 ...	3·002 „	11·55 „	2·453 „	12·07 „

The average total cost of conveying a ton of goods over one mile of the Madras Railway may thus be taken at about 4 pies. On the East Indian Railway the expense should be less, as it pays less for fuel, and its gradients are much more favorable: $3\frac{1}{2}$ pies per ton per mile is thus likely to be pretty near the mark. The Railway charge for conveying coal from Raneegunge to Calcutta is 7 pies per ton per mile, the difference $3\frac{1}{2}$ pies going to cover interest on capital and to yield a profit.

Captain Garnault's comparison seems to be all fair, except that he does not apparently allow any profit to the boat-owner, and that he under-estimates the time which would be occupied in going up and

down the canal. The result he arrives at is that the cost per ton of coal would be Rupees 4-8 by rail and Rupees 2-2 by canal. I think the following would be more likely to be correct:—

Boat, 30 tons

Monthly charge, Rupees 60,

allow two trips per mensem, namely, four days down the canal, four days loading and unloading, and seven days up the canal.

Cost of boat, Rupees 3,000,

allow 15 per cent for interest and wear and tear: this comes to Rupees 450 per annum, or Rupees 18-12 for half a month.

The cost of one trip would thus be—

			Rs.	As.	P.
Charge of boat	...	...	18	12	0
Mangies	...	...	30	0	0
Toll	...	...	30	0	0
Sundries, 10 per cent.	...	...	7	14	0
Total			86	10	0

or per ton, supposing the boat to return empty, Rupees 2-14. If we suppose that the Railway *profit* is 8 annas per ton, and that a like profit is allowed the boat-owner, we should have Rupees 4 per ton by rail and Rupees 2-14 by boat without profit, or Rupees 4-8 and Rupees 3-6, respectively, with profit; the difference in favor of the canal being Rupees 1-2, instead of Rupees 2-6 as computed by Captain Garnault. The difference would be half a Rupee more if the toll were to be 8 annas a ton, as the Government of India suggested, instead of the 1 Rupee proposed by Colonel Rundall.

If the Railway were to enter into competition with the canal and to reduce its rates to 5½ pies per ton per mile, the charge from Raneegunge to Howrah would be Rupees 3-7, or almost identical with the computed charge by boat with a Government toll at 1 Rupee per ton.

On the Madras Delta Canals stone is conveyed by native boats at the rate of 4 pies per ton per mile. The toll levied is 1 Rupee per

ton per annum on the capacity of the boat, so that a boat of 30 tons making 24 trips in the year would pay only 1-24th of a Rupee per ton of goods, that is, less than 1 anna. The above rate of 4⁰ pies per ton per mile, or Rupees 2-8 per 120 miles, less 1 anna for toll, would agree very closely with the calculation I have made of probable charges on the Damoodah Canal, seeing that the latter, exclusive of toll, come to Rupees 2-6 per ton.

I cannot say whether it would pay the Railway Company to reduce the charge for conveying coal to 5½ pies per ton per mile, or to whatever rate might be necessary to give it the preference over the canal ; but, in connection with this point, I venture to quote some remarks from an old American report,* which caught my eye several years ago, and which, as an acknowledgment by Railway officials of the injurious effects that had resulted from railways competing with canals, appeared to me particularly interesting and valuable.

* Appended.

The provision for accommodation of establishment allowed in the estimates is, I think, on a moderate scale, much more moderate than has been allowed on the canals in Upper India generally, and may therefore be approved, with one or two slight modifications.

With reference to the remark by Colonel Rundall in paragraph 18 of his note, that he does not see the use of making a river embankment 6 feet high above flood level, when the masonry works were to be only 3 feet higher, I may explain that the height mentioned was recommended for the embankments near the head works of the canal, simply because the crest of an earthen bank is more liable than masonry to be worn down by the action of water, traffic of foot passengers, or by accidental causes.

With regard to drainage, it may perhaps be unnecessary to complicate the canal question by insisting on its being combined with irrigation. As Mr. Adley is engaged in drawing up a project for the drainage of the low-lying lands to the west of Hooghly, and as there seems to be a fair prospect of its being carried into execution at the expense of the land-owners, the matter, so far as the canal is concerned, might stand over for the present. The Commissioner of Burdwan, however,

in comparing the canal to a slight scratch across the country, for all the effect it will have in adding to the existing defects of drainage, has probably not calculated the quantity of water which the canal is intended to distribute over the tract commanded by it. If the people take the canal water for their rice crops, they will take as much as they can get, which will be equivalent to an addition to the rainfall of 32 inches in 180 days over the computed area of irrigation, or $12\frac{1}{2}$ inches over the whole area commanded, and of course the effect of this additional water on low lands already injuriously swamped would not be at all insignificant.

Extract from Report of Railroad Commission, State of New York, year ending 30th September 1855, page XXII., &c., referred to in COLONEL ANDERSON'S Note on the Namoodah Canal Project.

An allusion has been made to the error so frequently committed in making large expenditures to secure through business, and for the consequent increase of equipment, depôt facilities, steam-boat connections, and aid to other railroads. It may be worth while to discuss these questions further.

A considerable portion of this increase of business has been obtained at an unwarrantable expense, and is done at too low rates to be profitable; while a large portion of the *legitimate* increase would have been received without effort on the part of the managers.

The stock-holders and the public are continually informed of these large receipts of the increase on those of former years, and the prospects of future business, all of which, they are led to believe, can be done without any corresponding increase of expense; but year by year they find that, with the realization of the full amount of the anticipated business, their *net* receipts are not only not increasing, but that meanwhile their stock has been diluted or their property loaded down with funded or floating debts, incurred to secure this illegitimate business, and also, that the expenses of working the road have increased faster than the proportionate increase of business.

The opinions of the late State Engineer are so opposite to these views that we cannot refrain from again extracting from his last report:

" The charges for transportation have been reduced to the present low rates from a mistaken opinion that it was necessary to show to the public large receipts, to accomplish which it was necessary to enter into a competition with rival roads and water lines, which was carried to an injurious extent in consequence of the fallacious statements of the expenses of transportation which the published reports exhibited.

" These reports, by exaggerating the net profits of the business, have prevented the managers, even when they discovered the error, from increasing their charges to compensating rates by the fear of public opinion and legislative interference.

" Upon any given line of railroad, there is a certain amount of travel and freight which would, in any event, be transported by it in preference to the water lines.

" In almost every case, the capacity of a well-equipped, single-track road, provided with frequent passing places and a telegraph for its exclusive use, would be sufficient for the performance of this legitimate business, which, if economically conducted, would yield the maximum profit which could be earned, and would, in most cases, be ample to assure either an immediate or an early profitable return for the investment.

" To divert from other roads any of this class of business requires a reduction in the charges, which must necessarily be extended further than merely to that portion which is diverted, and as the rate of cost of doing the business cannot be materially diminished, this reduction in the charge is taken directly from the net profits, and it therefore requires a large increase of business to yield the same amount of profit as was afforded before any reduction in the charges was made. This reduction is sometimes continued until no profit whatever is realized.

" The rival road from which the business is thus diverted will soon reduce its charges for the purpose of reclaiming its business, and feelings of rivalry will thus be engendered which will continue the

competition until the rates become so evidently unremunerative that conventions must be held to terminate the controversy and establish equitable prices and conditions. Each Company will then only be restored to its original position with the disadvantage of having in the meantime persuaded the public that the lowest prices were sufficiently remunerative.

“The alleged necessity of showing large receipts still exists; and the attempts to maintain the business diverted from rival roads being abandoned, a competition with the water lines is commenced for the transportation of the heavy and cheap articles of freight, which can only be maintained by rates nearly if not quite as low as those charged upon the lakes, rivers, and canals, and too low, as will presently be shown, to give a fair remuneration to the railroad.

“If the cost of railroad transportation could be determined with tolerable accuracy by some disinterested and official authority, it would be a great step taken towards the correction of some of the most serious evils to which allusion has been made.

“The sophistry of the argument, that it is ever the true interest of the shareholders to increase receipts, by carrying any portion of the business under cost, is too palpable to merit discussion. The public will always look with distrust upon the management which maintains so fallacious a doctrine.”

Despatch from the Government of India, to the Secretary of State for India,—(dated Simla, the 10th June 1870.)

In our despatch No. 97 dated 29th June 1869 we had the honor of forwarding, for the information of Her Majesty's Government, copies of reports on a proposed line of canal from the River Damoodah at Raneegunge to the Hooghly near Calcutta, and we mentioned that we had considered it necessary to call for more complete and detailed information on various points connected with the project before conveying our final approval of it. In reply, your Grace expressed a hope that no heavy expense would be incurred on certain preliminary operations which we had authorized until the project should have been fully matured. .

2. We have now received from the Government of Bengal the additional information we had called for. Revised plans and estimates have been drawn out, and have been submitted for our approval, accompanied by a strong recommendation in favor of the project by His Honor the Lieutenant-Governor. The Commissioner of Burdwan and other Revenue Officers have also furnished reports which contain much interesting information regarding the condition of the agriculture of the districts affected by the scheme, and its wants with regard to irrigation, and your Grace will observe that their opinion is generally favorable to the canal.

3. The Commissioner of Burdwan would appear to be not opposed to the levy of a compulsory rate for the water to be supplied for irrigation, since he says that "if all the irrigable land within reach of the canal and its distributaries is made liable by law to a certain rate for the use of the water, the cultivators will gladly avail themselves of the certainty thus given them, and the only dispute will be between them and the land-owners for their share of the profit." These expressions are, however, somewhat ambiguous, and may possibly mean that the rate should only be paid if the water is used. The Collector of Hooghly does not think there would be any demerit for artificial irrigation for the rice crops in the low-lying lands, except for a short time in October and November, unless there should be a total or partial failure of the ordinary rains, in which case a plentiful supply of water at a critical time might no doubt save the whole crop from destruction. He adds that on some of the land a superfluity and not a want of water is the obstacle to growing other and more remunerative crops than rice upon it. He also seems to think that a good deal of drainage is wanted, and if this is carried out, he does not believe that the ryots would be so blind to their own interests as to neglect the certain means of increasing the profits if placed within their reach. Water would be gladly taken and paid for the irrigation of sugar-cane and garden produce of various kinds, which are at present irrigated by lifts from khalls or tanks.

4. The Collector of Burdwan states that there is little fear of water stagnating in the low lands of his district as the fall of the surface is rapid, and he believes that the means that would be afforded by the canal of converting the inferior classes of land into a higher class, and

of generally increasing the produce, would prevent the ryots from being so bigoted or blind to their own interests as to refuse to pay for canal water. An influential zemindar, who has been consulted in the matter, gives evidence to much the same purport.

5. In the Officiating Inspector-General's Note on the former estimates, it was stated that the rice crops must be already raised by irrigation. It now appears that he was wrong in this point, having apparently been misled by a statement of the Collector of Hooghly, quoted by Captain Garnault in his report on the project, to the effect that he believed the area of land irrigated to be nearly equal to the area of the district. It is now explained that the rice crops are almost entirely dependent on the direct rainfall for their supply of water, and that this supply is frequently insufficient to produce a full crop. In the past year, it is said that the outturn in the Burdwan district would not be above three-quarters of a full crop.

6. On this point we may observe that we never doubted that irrigation, especially if combined with a system of drainage, could be used with great advantage in these districts. What we doubted was, whether the people would take the canal water *regularly*. The estimate of returns has been made on the assumption that the full value of the water will be realized every year, and, considering that even in this case the Government would have to wait a number of years before the canal could come into full operation, the computed receipts of 10 per cent on the outlay would not be much more than sufficient to make the undertaking really profitable.

7. Great stress is laid by His Honor the Lieutenant-Governor on the fact that the Government of India has recognized the *necessity* "for providing, as early as possible, any practicable means for protecting the population of Western Bengal from the effects of drought, which have been felt with special severity during the last few years." Admitting this, we still are of opinion that the greater the necessity that exists for providing means of irrigation in view either to confer a direct advantage on a rich and populous district, or to avert loss from it, the stronger are the reasons for taking measures to prevent any pecuniary loss to Government, which may thereby be sustained, from falling on other districts in the form of increased taxation; in other words, we

consider it essential that irrigation works should themselves furnish the means of paying the interest of the borrowed money with which they are carried out.

8. Unfortunately we have few facts to lead us to any conclusions with regard to the opening available for artificial irrigation of a remunerative character in most of the Bengal districts. The works in Midnapore and Orissa, which, if allowance were made for the difference of condition with regard to rainfall, would afford a fair standard for judging of the probable effect of a canal from the Damoodah, are still in a very early stage of development. Out of an area of nearly 200,000 acres, which the distributaries that have been opened out from the new canals now give the means of irrigating, between 22 and 23,000 acres only appear to have been irrigated in 1868. The Chief Engineer, in his report dated 20th September last, paragraph 55, computes the area likely to be irrigated in the following year at about 50,000 acres. But we have not yet received the returns of the areas actually irrigated, and are not aware whether this expectation has been realized. We await the returns with great interest, and should it appear that the receipts of the past and, perhaps, also of the present year exhibit a progressive increase to the extent anticipated by the local authorities, we should be encouraged to apply the results to the projected canal from the Damoodah, with such modifications as the difference of rainfall in the two localities might seem to require. But at present we regret that we have not sufficient grounds to warrant us in believing that the receipts from irrigation under the Damoodah Canal would reach the amount estimated by the Bengal Government, or that they would be sufficient to cover the interest on the capital outlay.

9. And the conditions of the canal as a line of navigation have been considerably changed by a report we have recently received of the discovery of a good quality of coal at Midnapore. It would be premature to draw any conclusions as to the probable results of this discovery; but should it lead to a coal field equal to that at Raneegunge being found at Midnapore or the neighbourhood, one of the principal objects for which the Damoodah Canal was originally taken up would no longer exist; since, as the distance from Midnapore to Calcutta is

between 40 to 50 miles less than that from Raneegunge, merchants would bring coal to Calcutta by the former route in preference to the other. Moreover, the Midnapore Canal, which will afford a water communication with the Hooghly, is likely to be completed within two years from this date.

10. If the canal from the Domoodah were adapted for irrigation only, the saving would not be so great as might be anticipated; for the weir across the river, several expensive aqueducts and the first 66 miles of the canal would be unaffected by the arrangement, except that the Locks would be omitted. But the total saving by cutting out these works, and the last 24 or 25 miles of main channel, would not at the most exceed 15 lakhs of Rupees (£150,000), while the total amount of estimates now submitted is £515,000 (Rupees 51,49,700), which would be further increased by two lakhs (£20,000) if the Locks are made 150 feet long and 20 feet wide, instead of 100 feet by 17 feet as proposed by the Engineers.

11. Under these circumstances we have considered it inadvisable to proceed further with the works in the canal without the express authority of Her Majesty's Government, and we have accordingly requested the Bengal Government to suspend the operations which we sanctioned more than a year ago.* The expenditure up to the end of March last amounted to £5,096, and is not likely by this date to have reached £7,500.

* Despatch No. 97 dated 9th July 1869.

12. Perhaps your Grace, in consideration of the strong arguments advanced by His Honor the Lieutenant-Governor in favor of the present scheme, may think that it may be proceeded with without risk of financial failure or loss, either to the extent provided for in the estimates, or as an irrigation work only pending the result of the further enquiries now being instituted consequent on the discovery, as above-mentioned, of coal at Midnapore. But in our opinion it would be better to wait until the returns from the works already in operation in the Midnapore and Cuttack district are placed on a more secure basis than they can be said to be at present.

13. With regard to the revised estimates now submitted, it is only necessary for us to explain that they are generally in accordance

with the former orders or suggestions of the Government of India. Both the plans and estimates have been drawn up with much care, and we consider that Captain Garnault's designs for the works, as well as his explanatory reports, mark him as an officer of distinguished ability.

14. As above-mentioned, the estimates now received amount to £514,970 (Rupees 51,49,700). If Locks 150 feet by 20 feet are adopted, this amount will be increased by two lakhs of Rupees (£20,000) ; and allowing 12 per cent for establishments, the total probable cost of the canal would be nearly £600,000. The returns, as computed by the Chief Engineer, are as follows :--

	Rupees.
200,000 acres of rice at Rs. 1-8 ...	3,00,000
64,000 „ cold weather crop at Rs. 3 ...	1,92,000
	<hr/>
	4,92,000
<i>Navigation.</i>	
200,000 tons of coal at 1 Rupee ...	2,00,000
100,000 „ stone-lime, &c., at 1 Rupee	1,00,000
200,000 „ sundries ...	1,00,000
	<hr/>
	4,00,000
	<hr/>
Total ...	8,92,000
	<hr/>
	£89,200
	<hr/>

Deducting 5 per cent on prime cost for maintenance, which is perhaps a somewhat high rate, we should, according to the above calculation, have a net return of 10 per cent on the outlay.

15. We forward an abstract of the estimates for your Grace's information, also the whole of the plans connected with the project. We have not thought it necessary to retain the latter until copies could be made, but these will be sent hereafter if required, if your Grace will be so good as to return the originals.

Several points of a technical character have been noticed by our Officiating Inspector-General of Irrigation in his note on the estimates, and an extract is attached, to which we invite your Grace's attention.

16. In conclusion, we do ourselves the honor of forwarding a copy of the instructions we have issued with regard to the suspension of preliminary operations at the head of the canal, until the project should receive the sanction of Her Majesty's Government.

Extract paragraphs 1 to 3 of a Despatch from Secretary of State for India, to the Government of India, No. 73, dated 14th September 1870,—(received from Government of India, under date 18th November 1870.)

1. I have had before me in Council your Excellency's Despatch No. 76 of 10th June last, informing me that you have considered it unadvisable to proceed further with the project for a canal from the Damoodah to the Hooghly without the express authority of Her Majesty's Government, and that you have accordingly ordered the operations, sanctioned more than a year ago, to be suspended.

2. I approve of this decision, which seems to me to have been, in the circumstances reported, the only one at which you could have arrived consistently with the principles laid down by your Government for general guidance in the selection of Irrigation projects to be executed as "Extraordinary" works with borrowed money. At present there are not, you say, sufficient grounds to warrant you in believing that the receipts from irrigation will suffice to cover the interest on the capital, while, with respect to receipts from navigation, it is quite possible that expectation as to these might be completely disappointed by competition of the Midnapore coal field and canal with those named after the Damoodah.

3. I cannot think, therefore, that the scheme under consideration could be proceeded with immediately without risk of serious financial loss. I join in opinion with your Excellency, that it will be wiser to wait until observation of the Irrigation and Navigation Works in operation in the Midnapore and Cuttack districts shall have afforded better means of judging what will be the probable effects of similar works in the country between Raneegunge and Calcutta.

A P P E N D I C E S

REFERRED TO

IN

LIEUT. HEYWOOD'S REPORT,

PAGE 46.

APPENDIX I.

1860.

DATE.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	TOTAL.
							Ft.In.	Ft.In.	Ft.In.	Ft.In.	Ft.In.	Ft.In.	
1st	-	-	-	-	-	-	5 9	7 9	4 6	3 2	1 2	0 5	
2nd	-	-	-	-	-	-	5 5	7 8	5 7	3 5	1 1	0 5	
3rd	-	-	-	-	-	-	5 1	7 6	5 10	6 6	1 1	0 4	
4th	-	-	-	-	-	-	5 0	7 10	5 9	6 0	1 0	0 4	
5th	-	-	-	-	-	-	4 8	7 9	5 6	6 2	0 11	0 4	
6th	-	-	-	-	-	-	4 4	7 6	4 8	5 6	0 11	0 4	
7th	-	-	-	-	-	-	4 1	10 7	4 3	4 0	0 10	0 4	
8th	-	-	-	-	-	-	9 0	6 10	3 10	4 3	0 10	0 4	
9th	-	-	-	-	-	-	8 6	6 8	4 9	3 6	0 10	0 4	
10th	-	-	-	-	-	-	6 9	6 0	7 0	3 1	0 10	0 4	
11th	-	-	-	-	-	-	5 3	5 8	7 6	2 9	0 9	0 4	
12th	-	-	-	-	-	-	4 9	5 11	6 7	2 3	0 9	0 4	
13th	-	-	-	-	-	-	4 6	8 0	5 11	2 3	0 9	0 4	
14th	-	-	-	-	-	-	4 2	8 6	5 0	2 1	0 9	0 4	
15th	-	-	-	-	-	-	3 4	7 6	4 6	1 11	0 8	0 4	
16th	-	-	-	-	-	-	3 0	7 0	4 0	1 10	0 8	0 4	
17th	-	-	-	-	-	-	3 0	13 0	3 8	3 6	0 8	0 4	
18th	-	-	-	-	-	-	3 2	10 0	6 1	3 1	0 8	0 4	
19th	-	-	-	-	-	-	5 0	7 9	5 10	2 9	0 7	0 3	
20th	-	-	-	-	-	-	5 0	6 11	5 8	2 3	0 7	0 3	
21st	-	-	-	-	-	-	6 6	6 10	6 2	2 3	0 7	0 3	
22nd	-	-	-	-	-	-	10 3	10 9	6 2	2 1	0 7	0 3	
23rd	-	-	-	-	-	-	10 0	12 3	5 4	1 11	0 7	0 3	
24th	-	-	-	-	-	-	9 0	8 3	5 1	1 10	0 7	0 3	
25th	-	-	-	-	-	-	17 0	7 6	4 10	1 9	0 6	0 3	
26th	-	-	-	-	-	-	18 0	6 6	4 8	1 7	0 6	0 3	
27th	-	-	-	-	-	-	12 9	7 4	4 7	1 6	0 6	0 2	
28th	-	-	-	-	-	-	12 6	6 2	4 2	1 5	0 6	0 2	
29th	-	-	-	-	-	-	10 3	5 5	5 9	1 4	0 5	0 2	
30th	-	-	-	-	-	-	8 6	4 10	3 1	1 4	0 5	0 2	
31st	-	-	-	-	-	-	7 9	4 8	...	1 2	...	0 2	
							145,797,656,000	116,175,973,800	32,031,702,000	8,820,034,000	69,797,300	24,338,000	302,851,551,500 Cubic feet.

1861.

DATE.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		TOTAL.
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	
1st -	0	2	0	3	0	2	0	3	0	4	8	7	3	11	6	6	5	6	7	5	4	9	3	4	819,579,786,120 Cubic feet.
2nd -	0	2	0	2	0	1½	0	3	0	3	7	7	3	10	6	10	13	10	7	3	4	7	3	3	
3rd -	0	2	0	2	0	1½	0	2	0	3½	7	9	3	6	8	6	10	9	7	6	4	6	3	3	
4th -	0	2	0	2	0	1½	0	1	0	3	7	3	13	6	8	0	9	1	12	6	4	5	3	3	
5th -	0	2	0	1	0	1½	0	1	0	2½	7	9	15	9	6	9	19	6	11	6	4	4	3	3	
6th -	0	2	0	1	0	1½	0	0½	0	2	6	2	11	1	5	4	11	0	10	10	4	4	3	3	
7th -	0	2	0	1	0	1½	0	3	0	3	5	3	9	8	5	9	12	0	13	5	4	11	3	2	
8th -	0	1	0	1	0	1	0	3	0	3½	5	1	8	6	8	7	9	8	11	6	5	2	3	2	
9th -	0	1	0	1	0	1	0	0½	0	3	4	9	7	8	8	7	8	0	9	6	5	2	3	2	
10th -	0	1	0	1	0	2	0	0½	0	5	4	1	9	3	7	9	8	5	11	6	5	4	3	2	
11th -	0	1	0	1	0	1½	0	0½	0	7	5	9	7	10	8	4	11	5	12	0	5	1	3	10	
12th -	0	1	0	1	0	2	0	1	0	6	5	1	8	9	7	5	11	0	14	5	5	2	4	0	
13th -	0	1	0	1	0	10	0	1	0	2	8	9	7	6	8	6	10	2	14	8	5	2	3	10	
14th -	0	2	0	0½	0	7	0	0½	0	9	7	6	6	6	7	6	9	3	10	9	4	9	3	7	
15th -	0	4	0	0½	0	10	0	1½	0	8	7	0	6	0	5	9	8	9	9	3	4	6	3	5	
16th -	0	4	0	0½	0	7	0	1½	0	6½	5	3	5	4	4	10	7	7	8	5	4	3	3	6	
17th -	0	4	0	2	2	3	0	2	1	11	4	8	4	6	4	1	7	1	8	0	4	1	3	9	
18th -	0	4	0	2	1	10	0	2	1	11	4	7	4	3	3	9	6	5	9	0	4	0	4	4	
19th -	0	3	0	2	1	6	0	2½	1	8	3	10	5	1	3	8	6	7	8	6	3	11	4	4	
20th -	0	3	0	2	1	3	0	2½	1	4	3	3	11	5	4	6	9	0	7	9	3	10	3	10	
21st -	0	3	0	2	1	2	0	2½	1	2	11	10	13	3	7	2	9	2	6	11	3	9	3	7	
22nd -	0	3	0	2	0	11	0	3	0	11	13	4	12	6	10	5	14	0	6	5	3	8	3	6	
23rd -	0	3	0	2	0	10	0	3	1	4	13	2	10	2	10	1	11	9	6	8	3	7	3	5	
24th -	0	7	0	2	1	9	0	3	3	10	11	6	9	3	10	3	9	7	6	9	3	7	3	3	
25th -	0	6	0	2	0	8	0	3	3	2	9	3	8	0	9	4	7	11	6	4	3	6	3	2	
26th -	0	5	0	2	0	7	0	3	4	7	7	6	11	1	9	0	7	2	6	0	3	6	3	1	
27th -	0	4	0	2	0	6	0	1½	3	3	8	6	10	0	7	10	12	0	5	8	3	5	3	0	
28th -	0	4	0	2	0	5	0	0½	2	6	6	6	9	2	6	8	9	0	5	3	3	5	3	0	
29th -	0	4	...	...	0	5	0	6	2	4	6	3	9	1	6	10	7	9	5	4	3	4	2	11
30th -	0	3	...	...	0	4	0	5½	6	4	4	10	8	2	7	6	6	11	11	4	3	4	2	11
31st -	0	3	...	...	0	4	...	...	8	5	...	...	7	2	6	2	...	10	4	...	...	2	10	
22,953,000		10,773,000		135,013,720		15,989,000		10,064,084,800		95,246,146,000		176,296,866,000		102,254,083,400		212,020,134,000		200,961,466,400		14,984,334,800		7,587,966,400			

DATE.		January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		TOTAL.	
		Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.		
1st	-	3	0	2	5	1	10	1	9	2	0	1	5	8	3	6	10	10	8	5	11	6	2	4	2		
2nd	-	3	0	2	5	1	10	1	9	1	11	1	4	8	0	6	4	10	0	5	0	6	0	4	2		
3rd	-	3	0	2	4	1	9	1	8	2	6	1	6	9	9	5	6	8	6	5	0	5	11	4	2		
4th	-	3	0	2	4	1	9	1	8	2	3	1	4	10	8	5	8	7	8	5	9	5	9	4	1		
5th	-	2	11	2	4	1	8	1	7	2	1	1	3	8	7	7	6	7	0	7	7	5	7	4	1		
6th	-	2	11	2	3	1	8	1	7	2	6	1	3	10	6	7	1	8	3	6	5	5	6	4	1		
7th	-	2	10	2	3	1	8	1	6	3	4	1	2	14	1	8	0	7	7	14	9	5	4	4	1		
8th	-	2	10	2	3	1	8	1	6	4	8	1	2	10	2	6	8	8	5	13	6	5	3	4	0		
9th	-	2	10	2	3	1	7	1	5	3	4	1	2	9	7	6	11	6	11	11	8	5	2	4	0		
10th	-	2	10	2	2	1	7	1	5	3	2	1	1	8	4	6	10	8	6	9	3	5	1	4	0		
11th	-	2	9	2	2	2	3	1	4	6	0	1	1	8	2	10	6	6	11	7	9	5	1	4	0		
12th	-	2	9	2	2	4	11	1	4	4	0	1	1	10	8	9	0	6	0	8	3	5	0	4	0		
13th	-	2	9	2	1	4	7	1	4	3	4	1	1	14	2	7	10	7	9	9	9	5	0	4	0		
14th	-	2	9	2	1	3	9	1	3	3	1	1	1	10	10	7	3	8	6	9	8	4	11	3	11		
15th	-	2	9	2	1	3	6	1	3	2	8	3	0	14	0	9	7	8	3	10	8	4	11	3	11		
16th	-	2	9	2	1	3	2	1	3	2	8	2	7	11	5	8	6	7	5	9	10	4	10	3	11		
17th	-	2	9	2	1	2	9	1	2	2	6	3	3	13	9	12	6	7	10	8	3	4	8	3	11		
18th	-	2	10	2	1	2	7	1	2	2	5	4	11	12	10	12	9	6	7	7	0	4	7	3	11		
19th	-	3	5	2	1	2	6	1	2	2	4	14	6	9	8	10	6	6	0	6	0	4	6	3	11		
20th	-	3	8	2	1	2	4	1	7	2	2	12	6	7	9	8	4	6	3	5	10	4	6	3	11		
21st	-	3	2	2	1	2	3	1	7	2	4	10	6	12	5	7	3	7	7	5	7	4	5	3	10		
22nd	-	2	7	2	1	2	2	1	7	2	0	8	3	11	9	8	0	5	10	5	6	4	5	3	10		
23rd	-	2	3	2	0	2	1	1	2	1	11	7	3	7	8	8	10	5	4	7	9	4	5	3	10		
24th	-	2	0	2	0	2	0	1	1	2	5	6	7	16	0	12	8	5	6	13	4	4	4	3	10		
25th	-	2	10	2	0	1	11	1	3	2	4	7	4	11	0	15	2	6	1	11	9	4	4	3	10		
26th	-	2	9	2	0	1	10	1	2	2	1	7	2	9	3	12	6	8	5	9	9	4	3	3	10		
27th	-	2	8	1	11	1	10	1	1	2	0	11	3	13	5	13	5	8	1	8	4	4	3	3	10		
28th	-	2	7	1	11	1	9	1	2	1	10	8	4	11	6	11	3	10	0	7	5	4	3	3	9		
29th	-	2	6	..	..	1	8	1	2	1	9	7	4	12	11	11	6	8	2	6	11	4	2	3	9		
30th	-	2	5	..	..	2	0	1	3	1	7	6	9	8	6	14	6	7	1	6	6	4	2	3	9		
31st	-	2	5	..	..	1	11	..	..	1	6	..	..	6	0	12	6	..	..	6	4	..	..	3	9		
		3,578,987,200		1,208,944,800		2,855,041,600		350,134,000		3,687,264,400		72,383,543,200		273,933,083,200		218,700,055,600		105,404,688,000		154,966,969,200		23,162,583,000		12,337,402,000		972,579,796,400 Cubic feet.	

1863.

DATE.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		TOTAL.
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	
1st	3	9	3	5	2	11	2	1	2	1	2	3	6	6	7	11	6	9	18	8	4	7	3	6	737,832,158,400 Cubic feet.
2nd	3	8	3	5	2	11	2	1	2	0	2	2	13	3	8	0	5	9	15	3	4	7	3	6	
3rd	3	8	3	4	2	10	2	1	2	0	2	0	9	5	8	5	7	2	11	2	4	6	3	5	
4th	3	8	3	4	2	10	2	0	1	11	1	10	9	8	7	4	6	10	9	6	4	6	3	5	
5th	3	8	3	4	2	9	2	0	1	11	1	8	10	7	7	11	7	2	8	9	4	5	3	5	
6th	3	8	3	4	2	9	2	0	1	11	1	6	11	0	13	0	7	11	9	6	4	5	3	5	
7th	3	7	3	3	2	8	2	0	1	10	1	6	13	5	9	9	7	4	11	6	4	4	3	4	
8th	3	7	3	3	2	8	1	11	2	3	2	0	11	6	8	10	6	6	12	9	4	4	3	4	
9th	3	7	3	3	2	7	1	11	3	0	2	7	9	9	7	9	5	6	9	9	4	3	3	4	
10th	3	7	3	3	2	7	1	11	2	11	2	8	7	7	7	8	4	8	8	6	4	3	3	4	
11th	3	7	3	2	2	7	1	11	2	10	6	1	6	2	8	0	4	3	7	9	4	2	3	4	
12th	3	7	3	2	2	6	1	11	2	9	6	3	5	6	7	5	4	0	7	6	4	2	4	3	
13th	3	7	3	2	2	6	1	11	2	10	9	2	5	6	6	11	3	10	7	3	4	3	3	3	
14th	3	7	3	2	2	6	1	11	2	9	8	6	6	0	6	7	3	11	7	6	4	1	3	3	
15th	3	6	3	2	2	5	1	11	2	10	7	0	8	14	6	8	8	0	6	11	4	1	3	3	
16th	3	6	3	2	2	5	1	11	3	0	13	6	10	6	6	3	14	7	6	6	4	0	3	3	
17th	3	6	3	2	2	5	1	10	3	1	9	6	11	0	5	11	10	6	6	3	4	0	3	3	
18th	3	7	3	2	2	5	1	10	2	10	7	9	11	2	9	3	9	9	6	0	3	11	3	2	
19th	3	9	3	2	2	4	3	6	2	11	6	1	11	5	12	9	8	5	5	10	3	11	3	2	
20th	3	10	3	1	2	4	3	6	7	9	6	4	10	9	11	0	7	2	5	8	3	10	3	2	
21st	3	9	3	1	2	4	3	2	5	8	5	5	9	3	11	0	6	6	5	6	3	10	3	2	
22nd	3	8	3	1	2	4	3	0	4	4	4	11	7	6	11	5	6	0	5	5	3	9	3	2	
23rd	3	8	3	1	2	3	2	10	3	9	8	0	8	3	10	8	7	9	5	4	3	9	3	2	
24th	3	7	3	1	2	3	2	7	3	6	8	2	7	0	8	7	11	7	5	3	3	8	3	2	
25th	3	7	3	0	2	3	2	6	3	6	1	10	6	1	7	7	16	4	5	2	3	8	3	2	
26th	3	7	3	0	2	3	2	5	3	5	9	9	1	0	6	7	16	0	5	1	3	7	3	2	
27th	3	7	3	0	2	4	2	4	3	0	3	2	6	2	5	8	13	2	5	0	3	7	3	1	
28th	3	6	3	0	2	4	2	3	2	10	10	6	7	0	5	3	11	8	4	11	3	7	3	1	
29th	3	6	...	...	2	4	2	2	2	8	8	3	10	0	5	0	9	7	4	10	3	6	3	1
30th	3	6	...	...	2	4	2	1	2	6	8	2	8	2	4	10	9	0	4	9	3	6	3	1
31st	3	5	...	...	2	1	...	...	2	5	...	...	8	0	4	6	...	...	4	8	...	...	3	1
9,392,859,200		5,043,358,900		2,401,669,600		2,065,837,600		8,117,422,400		79,017,100,000		174,008,806,600		138,454,359,000		171,057,432,000		127,280,794,000		14,412,866,400		6,539,572,800			

1864.

DATE.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		TOTAL.		
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.			
1st	3	1	2	7	2	5	1	10	1	4	6	2	6	10	11	8	5	0	5	10	3	9	3	5	530,134,463,400 Cubic feet.		
2nd	3	1	2	9	2	5	1	10	1	4	5	7	10	4	9	6	5	6	5	7	3	8	3	5			
3rd	3	0	2	9	2	5	1	9	1	4	5	4	8	6	11	5	6	6	5	3	3	7	3	5			
4th	3	0	2	9	2	5	1	9	1	3	5	9	9	2	13	0	6	4	5	0	3	7	3	5			
5th	3	0	2	9	2	5	1	8	1	11	5	9	8	6	10	3	6	0	4	10	4	0	3	4			
6th	3	0	2	9	2	5	1	8	1	10	4	9	6	9	12	9	6	5	4	11	6	5	3	4			
7th	3	0	2	9	2	4	1	7	1	9	4	1	5	9	12	3	8	10	4	9	6	1	3	4			
8th	3	0	2	9	2	4	1	7	1	8	3	9	7	3	11	10	7	6	4	9	5	6	3	4			
9th	3	0	2	8	2	4	1	7	1	7	3	6	5	11	9	8	7	4	4	8	4	11	3	4			
10th	3	0	2	8	2	4	1	7	1	7	3	3	5	8	12	9	9	0	4	7	4	7	3	4			
11th	2	11	2	8	2	3	1	6	1	9	3	3	5	2	10	3	17	6	4	6	4	6	3	4			
12th	2	11	2	8	2	5	1	6	1	8	3	11	5	1	8	10	12	8	5	6	4	5	3	4			
13th	2	11	2	8	2	6	1	6	1	8	3	9	4	7	9	0	10	9	6	5	4	6	3	3			
14th	2	11	2	8	2	4	1	6	2	6	4	9	6	10	8	9	7	8	6	3	4	4	3	3			
15th	2	11	2	8	2	10	1	6	2	4	4	8	9	11	8	8	10	7	5	4	4	3	3	3			
16th	2	11	2	7	2	11	1	7	3	3	4	1	8	6	8	14	5	7	4	11	4	2	3	3			
17th	2	11	2	8	2	9	1	7	1	4	4	8	6	11	7	6	6	10	1	10	4	1	3	3			
18th	2	11	2	8	2	8	1	7	1	4	5	6	6	9	6	7	8	0	4	6	4	1	3	3			
19th	2	11	2	9	2	7	1	7	1	4	5	0	7	0	6	14	8	6	4	5	3	11	3	3			
20th	2	11	2	9	2	6	1	8	1	4	4	7	8	3	7	5	7	10	4	4	3	10	3	3			
21st	2	11	2	8	2	5	1	8	2	6	4	5	14	0	6	11	8	2	1	3	3	9	3	3			
22nd	2	11	2	7	2	4	1	7	1	8	4	5	10	8	7	0	8	0	4	2	3	8	3	3			
23rd	2	11	2	7	2	3	1	6	2	3	4	0	9	8	8	2	8	6	4	1	3	7	3	2			
24th	2	11	2	7	2	2	1	6	2	2	5	6	8	11	11	0	8	6	4	0	3	6	3	2			
25th	2	10	2	6	2	2	1	6	3	2	3	5	7	8	9	2	7	3	4	0	3	6	3	2			
26th	2	10	2	6	2	1	1	5	2	11	3	6	6	5	7	5	6	6	3	11	3	6	3	2			
27th	2	10	2	6	2	1	1	5	2	9	4	3	12	0	6	8	6	2	3	10	3	6	3	2			
28th	2	10	2	6	2	0	1	5	2	7	4	3	9	0	6	0	5	10	3	9	3	6	3	2			
29th	2	10	2	6	2	0	1	4	2	6	0	0	8	3	5	7	5	9	3	8	3	5	3	2			
30th	2	10	..	..	1	11	1	4	2	8	7	8	9	0	5	2	6	1	3	8	3	5	3	2	
31st	2	10	..	..	1	11	..	..	3	9	..	..	10	3	5	0	..	..	3	8	..	..	3	1
		3,846,272,400		3,461,680,800		1,983,240,000		537,804,800		2,139,066,400		24,325,360,000		142,097,276,400		181,055,512,400		128,009,487,600		21,239,370,800		15,064,872,500		6,394,384,000		530,134,463,400 Cubic feet.	

1865.

DATE.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		TOTAL.
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	
1st	3	1	2	11	3	9	2	11	6	3	6	0	5	2	13	3	7	3	5	0	2	4	1	11	
2nd	3	1	2	11	4	0	2	10	5	5	5	5	5	1	14	6	7	8	4	1	2	4	1	11	
3rd	3	1	2	11	3	9	2	9	4	10	5	0	5	2	11	10	8	9	4	0	2	3	1	10	
4th	3	1	3	1	3	8	2	9	4	6	4	9	5	0	8	10	8	2	3	11	2	3	1	10	
5th	3	1	3	3	3	9	2	9	4	3	4	10	4	9	7	11	7	3	3	10	2	2	1	10	
6th	3	0	4	1	4	4	2	9	4	0	5	10	4	7	8	0	7	0	3	8	2	2	1	10	
7th	3	0	3	10	6	11	2	11	8	1	5	7	7	7	8	2	6	2	3	7	2	2	1	10	
8th	3	0	3	8	6	4	2	9	7	10	5	5	10	9	8	2	5	10	3	5	2	1	1	10	
9th	3	0	3	5	6	0	2	9	6	6	5	3	13	9	7	9	6	4	3	5	2	1	1	10	
10th	3	0	3	5	5	4	2	8	9	6	5	3	11	10	9	3	12	2	3	4	2	1	1	10	
11th	3	0	3	6	6	4	2	8	9	11	4	11	8	9	9	6	9	8	3	2	2	1	1	10	
12th	3	0	3	5	6	2	2	8	7	10	4	7	13	6	9	3	8	2	3	1	2	1	1	10	
13th	3	0	4	0	5	3	2	7	7	8	5	6	14	9	7	8	7	5	3	1	2	0	1	10	
14th	3	0	4	0	4	8	2	7	5	11	5	8	11	5	7	0	20	0	3	0	2	0	1	10	
15th	3	0	3	10	4	4	2	7	5	4	5	11	10	7	6	0	12	6	3	0	2	0	1	10	
16th	3	0	3	9	4	1	2	7	4	10	7	3	9	3	6	5	11	8	2	11	2	0	1	10	
17th	3	0	3	7	4	0	2	7	4	10	14	0	7	9	6	0	8	8	2	11	2	0	1	10	
18th	3	0	3	6	3	10	2	7	5	9	12	0	7	0	5	7	7	10	2	10	2	10	1	10	
19th	3	0	3	5	3	9	2	7	6	5	9	9	6	7	5	6	8	6	2	10	2	0	1	10	
20th	3	0	3	4	3	8	2	6	6	1	11	7	6	5	5	3	9	3	2	9	2	0	1	10	
21st	2	11	3	3	3	7	2	6	6	0	8	4	5	11	5	2	8	4	2	9	2	0	1	9	
22nd	2	11	3	2	3	6	2	6	7	2	7	3	5	6	5	0	8	7	2	8	2	0	1	9	
23rd	2	11	3	1	3	5	3	1	7	2	6	5	6	6	5	2	5	6	2	8	2	0	1	9	
24th	2	11	3	0	3	4	3	5	6	2	5	10	9	6	5	7	5	8	2	7	2	0	1	9	
25th	2	11	3	3	3	3	3	2	8	3	5	5	9	6	6	8	5	3	2	7	2	0	1	9	
26th	2	11	3	0	3	2	3	0	10	0	5	1	8	6	9	11	5	0	2	6	1	11	1	9	
27th	2	11	3	3	3	1	8	9	7	7	4	10	10	4	11	0	4	9	2	6	1	11	1	9	
28th	2	11	3	7	3	1	7	6	6	9	5	2	8	2	8	5	5	0	2	6	1	11	1	9	
29th	2	11	...	...	3	0	8	6	6	5	4	10	10	0	10	9	5	0	2	5	1	11	1	9	
30th	2	11	...	...	3	0	7	7	6	11	4	8	11	3	11	6	4	6	2	5	1	11	1	9	
31st	2	11	...	...	2	11	...	...	6	11	...	...	11	8	8	5	...	...	2	5	...	...	1	9	
																									4,078,722,000
																									7,063,979,700
																									18,865,246,900
																									18,427,618,300
																									76,186,478,800
																									76,869,595,600
																									178,163,569,600
																									143,629,235,600
																									141,612,705,600
																									5,611,535,600
																									1,073,991,600
																									760,194,000
																									674,414,965,200 Cubic feet.

vii
1866.

DATE.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	TOTAL.
	Ft.In.	Ft.In.	Ft.In.	Ft.In.	Ft.In.	Ft.In.	Ft.In.	Ft.In.	Ft.In.	Ft.In.	Ft.In.	Ft.In.	
1st -	1 9	1 8	2 5	1 1	8 3	1 3	18 6	4 5	8 6	6 3	6 11	3 3	
2nd -	1 9	1 9	2 4	1 2	5 1	1 3	19 6	5 11	8 5	5 11	6 6	3 3	
3rd -	1 8	1 10	2 2	3 2	5 3	1 3	16 2	10 5	8 5	7 2	6 1	3 3	
4th -	1 8	2 3	2 1	5 3	4 11	1 2	12 3	12 4	8 1	9 2	5 10	3 3	
5th -	1 8	2 3	1 11	5 2	4 4	1 2	9 11	11 2	8 0	8 6	5 6	2 3	
6th -	1 8	2 2	1 10	5 0	4 0	1 2	8 10	12 7	7 10	7 9	5 3	2 3	
7th -	1 8	2 1	1 9	4 9	3 8	1 2	7 5	12 5	9 11	7 3	4 11	1 3	
8th -	1 8	2 1	1 8	3 2	3 4	1 2	7 2	11 10	10 4	7 0	4 8	1 3	
9th -	1 8	2 1	1 7	2 11	2 11	1 2	6 10	11 2	10 0	6 7	4 5	3 0	
10th -	1 8	2 3	1 6	2 10	2 9	1 2	6 9	10 6	9 10	6 2	4 2	3 0	
11th -	1 8	2 9	1 5	2 8	2 5	1 2	6 6	10 2	13 0	5 11	4 1	3 0	
12th -	1 8	4 11	1 5	2 7	2 4	1 2	10 6	10 11	12 7	5 7	8 11	3 0	
13th -	1 9	5 2	1 5	2 4	2 1	1 2	7 11	10 10	11 0	5 5	3 10	3 0	
14th -	1 9	5 3	1 4	2 3	2 11	1 2	7 2	10 7	10 7	5 2	3 9	2 11	
15th -	1 9	4 9	1 4	2 2	1 10	1 2	6 9	9 10	10 8	4 11	3 9	2 11	
16th -	1 8	4 8	1 4	2 1	1 9	1 2	6 2	9 2	11 7	4 8	3 8	2 11	
17th -	1 8	4 7	1 4	1 11	1 8	1 2	10 9	8 9	11 1	4 8	3 8	2 11	
18th -	1 8	4 4	1 3	1 10	1 7	1 4	9 3	9 1	10 3	4 5	3 7	2 11	
19th -	1 8	4 0	1 3	1 9	1 7	5 11	10 2	12 10	9 8	4 3	3 7	2 11	
20th -	1 8	3 5	1 3	1 9	1 7	7 7	9 3	13 10	11 8	4 1	3 6	2 11	
21st -	1 8	2 9	1 3	1 8	1 6	10 6	8 10	13 10	11 11	3 11	3 6	2 10	
22nd -	1 8	2 9	1 2	2 0	1 6	12 0	8 4	14 0	11 10	3 10	3 5	2 10	
23rd -	1 9	3 7	1 2	1 10	1 6	11 7	7 8	14 11	10 6	3 7	3 7	2 10	
24th -	1 9	3 8	1 2	1 9	1 5	10 0	6 5	15 7	10 0	5 3	3 7	2 9	
25th -	1 8	3 6	1 2	1 8	1 5	10 2	6 0	15 0	9 7	10 4	3 5	2 9	
26th -	1 8	3 5	1 1	1 7	1 5	7 4	5 9	13 11	8 9	10 7	3 4	2 9	
27th -	1 8	2 9	1 1	1 7	1 4	6 9	5 7	11 7	8 1	9 9	3 4	2 8	
28th -	1 8	2 3	1 1	1 7	1 4	5 9	5 5	10 9	7 5	9 0	3 4	2 8	
29th -	1 8	..	1 1	1 9	1 4	5 7	5 3	10 1	6 11	8 5	3 3	2 7	
30th -	1 9	..	1 1	4 10	1 4	5 7	4 11	9 4	6 6	7 9	3 3	2 7	
31st -	1 9	..	1 1	..	1 3	..	4 8	9 0	..	7 4	..	2 6	
	664,463,200	7,319,989,400	507,753,600	6,225,906,400	6,606,129,600	68,436,523,600	166,049,151,200	316,526,661,600	207,417,846,800	80,313,303,200	16,723,709,400	3,451,989,600	889,791,081,200 Cubic feet.

APPENDIX II.

RAIN-FALL AT HAZAREEBAUGH.

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	TOTAL.	REMARKS.
1859	0.00	2.05	3.09	8.90	2.00	18.05	20.00	16.81	9.00	8.92	0.00	1.10	89.92	
1860	0.00	0.84	0.00	0.00	0.48	4.79	16.49	18.03	0.00	3.67	0.00	0.00	44.30	
1861	0.00	0.00	0.00	0.00	0.00	4.00	24.45	9.17	12.72	17.60	0.00	0.00	67.94	
1862	0.00	0.00	0.00	0.00	0.00	16.07	29.88	31.13	6.30	8.35	0.00	0.00	91.73	
1863	0.15	1.30	0.00	0.00	1.05	14.40	29.50	17.04	27.91	4.71	0.00	0.12	96.18	
1864	0.00	0.20	0.00	0.00	3.00	not taken*	12.16	7.06	2.35	2.38	1.98	0.00	40.64	* The mean fall in June during 7 years (11-51) has been entered for the fall in June 1864.
1865	0.95	1.09	4.39	2.80	16.86	6.06	29.09	10.66	6.13	0.00	0.50	0.00	78.53	
1866	1.00	3.00	0.00	3.70	0.00	17.19	22.01	22.25	18.84	6.68	0.30	0.00	94.97	
Mean	0.262	1.06	0.935	1.925	2.923	11.508	22.944	16.118	10.406	6.538	0.347	0.152	75.52	

RAIN-FALL AT PANCHEE.

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	TOTAL.	REMARKS.
1859..	0.00	0.50	2.70	2.30	1.70	9.90	10.20	6.60	1.45	3.54	0.00	0.30	39.19	
1860..	0.00	0.15	0.00	0.05	0.05	1.30	7.70	9.40	4.65	0.85	0.00	0.00	24.15	
1861..	0.75	0.00	0.85	0.10	4.80	3.10	12.45	4.40	7.40	2.90	0.30	1.30	38.35	
1862..	0.60	0.00	1.90	0.00	1.70	6.00	12.10	11.60	6.60	3.70	0.00	0.00	44.20	
1863..	0.00	0.40	0.00	0.00	0.00	8.70	16.85	3.10	7.10	4.55	0.00	0.00	40.70	
1864..	0.00	0.20	2.00	1.20	0.90	2.90	16.90	12.20	4.60	0.10	1.40	0.00	42.40	
1865..	0.50	2.05	1.95	0.40	4.20	5.10	11.40	8.30	4.30	0.00	0.00	0.00	38.20	
1866..	1.30	3.40	3.00	1.80	0.60	6.40	11.20	5.70	11.20	2.50	0.00	0.00	47.10	
Mean.	0.393	0.837	1.550	0.731	1.743	5.425	12.350	7.662	5.912	2.267	0.212	0.200	39.28	

RAIN-FALL AT BANCOORAH.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	REMARKS.
1859.	0.00	0.00	0.00	0.00	0.00	12.70	11.90	11.40	6.00	6.60	0.00	0.00	48.60	
1860.	0.00	0.20	1.00	2.10	0.10	4.40	13.10	5.60	10.55	2.70	0.00	0.00	39.75	
1861.	0.35	0.00	0.05	0.40	5.55	12.35	13.20	6.95	15.30	6.70	2.80	0.35	64.00	
1862.	0.80	0.00	0.20	2.70	2.00	10.30	22.10	7.65	5.00	11.65	0.00	0.00	62.40	
1863.	0.00	0.50	0.00	0.40	4.50	12.70	11.70	12.60	9.30	3.65	0.40	0.00	55.75	
1864.	0.00	0.00	0.30	1.80	3.70	4.80	9.50	9.50	9.20	1.05	0.00	0.00	39.85	
1865.	0.00	1.10	2.30	4.40	3.90	15.80	15.85	6.80	10.00	0.50	0.00	0.00	60.65	
1866.	1.45	7.25	0.55	2.20	1.60	15.05	16.00	10.85	8.95	2.70	0.00	0.00	66.60	
Mean.	0.325	1.131	0.550	1.750	2.668	11.012	14.168	8.918	9.287	4.413	0.400	0.043	54.70	

RAIN-FALL AT BURDWAN.

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	TOTAL.	REMARKS.
1859..	0.00	1.00	7.80	2.40	6.70	7.50	11.10	11.20	5.40	3.60	0.00	0.00	56.70	
1860..	0.00	0.20	1.20	4.00	2.80	11.80	12.20	11.80	11.30	3.60	2.00	0.00	60.90	
1861..	0.00	0.00	0.70	0.70	5.80	15.80	24.95	7.20	17.90	11.20	1.30	0.35	85.30	
1862..	0.20	0.00	0.70	0.50	4.40	8.95	18.65	5.85	7.75	12.65	0.00	0.00	62.65	
1863..	0.00	0.50	0.00	1.65	4.45	11.50	8.80	15.30	4.95	2.00	0.30	0.00	49.45	
1864..	0.00	1.20	0.70	0.70	5.90	6.15	14.25	10.20	4.80	0.80	0.50	0.00	44.40	
1865..	0.00	3.30	1.80	2.00	13.85	7.90	13.05	5.80	7.95	0.00	0.00	0.40	56.05	
1866..	1.75	6.65	0.60	2.70	2.10	13.85	14.80	12.80	6.20	2.20	0.00	0.00	63.65	
Mean.	0.243	1.606	1.612	2.206	5.750	10.431	14.725	10.018	8.181	4.506	0.512	0.093	59.88	

RAIN-FALL AT CALCUTTA.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	REMARKS.
1859..	0.00	0.66	4.23	1.29	3.18	12.48	9.09	21.22	11.55	4.96	0.00	0.00	68.66	
1860..	0.00	0.09	0.00	2.47	2.21	6.46	17.92	14.65	7.13	1.68	0.00	0.00	52.61	
1861..	0.56	0.00	0.88	0.31	9.07	26.44	10.93	16.12	12.48	7.75	4.39	0.26	89.19	
1862..	1.03	0.00	1.69	2.53	3.80	13.63	13.31	12.03	10.86	14.40	0.00	0.20	73.48	
1863..	0.00	1.20	0.00	2.43	4.20	12.93	11.22	14.10	10.33	3.48	1.26	0.00	61.15	
1864..	0.00	0.47	1.84	1.11	10.36	18.73	13.09	16.64	12.59	6.50	2.89	0.00	84.22	
1865..	0.48	1.86	1.96	4.28	15.94	8.63	12.19	5.99	10.25	0.00	0.00	0.00	61.58	
1866..	1.91	3.74	0.00	1.81	2.56	7.02	13.42	11.48	15.97	7.83	0.00	0.00	65.74	
Mean.	0.497	1.002	1.325	2.028	6.415	13.290	12.646	14.028	11.395	5.825	1.067	0.057	69.57	

